HUMBER RIVER BACTERIOLOGICAL STUDY

TECHNICAL REPORT #6

A REPORT
OF THE

TORONTO AREA WATERSHED
MANAGEMENT STRATEGY
STEERING COMMITTEE

DECEMBER, 1985

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Prepared by:

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Toronto, Ontario

December, 1985

TORONTO AREA WATERSHED MANAGEMENT STRATEGY STEERING COMMITTEE MEMBER AGENCIES

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EXECUTIVE SUMMARY

A bacteriological study was carried out in Humber River Basin as part of the Toronto Area Watershed Management Study (TAWMS). The main objectives of the study were: 1. To establish the bacteriological quality of the Humber River relative to applicable MOE Provincial Water Quality Objectives (PWQO); and 2. To identify the origins of fecal contamination in the Humber River. The study area included the main Humber River from Steeles Avenue to Lakeshore Boulevard and Black Creek from Lawrence Avenue to its confluence with the Humber River. There were four stations on Humber River and two stations on Black Creek as follows:

1. Humber River at Lakeshore Boulevard
2. Humber River at Dundas Street
3. Humber River at James Gardens
4. Humber River at Steeles Avenue
5. Black Creek at Scarlett Road
6. Black Creek at Lawrence Avenue

Ten dry weather surveys were carried out during September 12 - October 25, 1983, including one Sunday sampling. Two wet weather events were monitored during October 3 - 4, 1983 and November 15 - 17, 1983. The bacteriological parameters monitored include fecal coliforms (FC), fecal streptococci (FS), Enterococci, E.coli and P.aeruginosa. The recreational water quality objectives, as per the PWQO for FC and the IJC recommended objectives for other parameters were as follows:

FC	:	100/100 mL (MOE PWQO)
E.coli	:	23/100 mL (IJC)
Enterococci	:	11/100 mL (IJC)
P.aeruginosa	:	not greater than 10/100 mL in more than 25% of the analyses (IJC)

The above objectives are the geometric means of a series of samples collected at one location over a 30-day period, the minimum number being ten for FC (MOE PWQO) and five for the other parameters (IJC). At present, there are no PWQO for Enterococci, E.coli and P.aeruginosa; therefore, the IJC recommended objectives have been utilized to interpret the broader bacteriological data collected in this study. There are no objectives for FS, but the ratios

(FC/FS) are considered to be indicative of possible sources of fecal contamination. Herein, the FC/FS ratios established recently in a MOE-sponsored research study have been utilized to interpret the results.

The main conclusions resulting from this study are as follows:

- For dry weather conditions, the geometric mean densities were in noncompliance with the objectives in the case of:

  - FC at all stations;

  - Enterococci in Humber River at Lakeshore and Dundas, and in Black Creek at Scarlett and Lawrence;

  - E.coli at all stations;

  - P.aeruginosa at all stations except Humber River at Dundas and Steeles.

- Generally, the dry weather bacterial densities in Black Creek were at least five times greater than those in Humber River.

- The ratios (FC/FS) for the dry weather conditions were 8.46 in Black Creek at Scarlett and 7.71 in the Humber River at Lakeshore. These could indicate the presence of either a fresh mixture of non-human animal fecal sources located close to these two stations, or a mixture of human and non-human sources located farther upstream from the stations. At all other locations, the ratios were generally in the range 1.4 to 3.6, indicating either fresh non-human animal fecal sources close to the sampling stations or a mixture of human and non-human waste sources located farther upstream.

- Densities of FC, Enterococci, E.coli and P.aeruginosa increased from upstream to downstream locations during dry weather at all stations except for a slight decline of P.aeruginosa in Black Creek. These four bacterial parameters were in noncompliance with the appropriate PWQO and IJC recommended objectives in all the 10 samples from Black Creek at Scarlett Road.

- The geometric mean density of each bacterial parameter for each wet weather event was in noncompliance with the objective for that parameter.

- The densities in Black Creek were at least five times greater than those in Humber River during wet weather events, as in the case of the dry weather studies.

- There was an increase in the wet weather densities of various parameters from upstream to downstream locations as well, except for a decline of FS in Black Creek in the October event.

- A comparison of dry and wet weather results indicates that bacterial densities were 3.4 to 377.1 times higher in wet weather, Enterococci showing the largest increase.

- An evaluation of the impact of dry weather outfall FC and FS loading inputs on instream bacterial quality using a mass balance approach with first-order die-off indicates that the computed dry weather FC and FS densities are very close to the observations at all locations except that the computed FC was 50% of the observed density in the Humber River above James Gardens and the computed FS was 236% of the observed value in the Humber River at Lakeshore Blvd. Given the various assumptions and limitations of the computational procedure, the dry weather outfall loading appears to be one of the main sources of fecal contamination of the streamwaters, and that there is a possibility of the presence of additional FC bacterial sources in the Humber River above James Gardens.

- The data collected during the TAWMS Fall 1982 and July 1983, and present studies show that the bacteriological quality in the two water courses within the study area is in noncompliance with the PWQO and IJC recommended objectives; hence, the entire study area is a "problem area", Black Creek being the most highly contaminated area.

- Based on the relative values of (FC/FS) ratios, the possible sources of fecal contamination at all locations seem to be a mixture of human-origin and non-human animal waste sources. However, the ratios at Black Creek above Scarlett and Humber River above Lakeshore suggest

possible fecal contamination by human and animal (dog) waste sources. The detailed studies for identification of bacterial species, being carried out by the MOE Microbiology Laboratory, are likely to define the origin of waste sources more precisely than is possible in this study.

- An assessment of bacteriological trends shows that the FC levels and FC/FS ratios declined in the Humber River at Bolton; no significant trend with time exists in FC levels in Black Creek at Scarlett Road or the Humber River at Lakeshore; FC/FS ratios increased since 1980 in Black Creek at Scarlett Road.

- It is recommended that future recreational water quality assessment studies include:

  - development of a methodology to evaluate the effect of wet weather bacterial densities in interpreting the water quality objectives

  - selection of sampling stations by considering the waste source and water use locations, and, factors and processes affecting bacterial transport in streams and rivers

  - sediment phase monitoring to permit detailed mass balance computations

  - estimation of bacterial growth and die-off rates

  - bacterial inputs from other sources such as water fowl, animals, etc.

ACKNOWLEDGEMENTS

We are thankful to Messrs. Don Weatherbe, Brian Whitehead and Michael Young for providing constructive suggestions during various stages of this study. Our thanks are also due to Mr. Allan Bacchus for his helpful suggestions of field study aspects.

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1 INTRODUCTION

1.1 Problem Definition

Bacterial pollution of various water courses in the Metropolitan Toronto area has resulted in the closure of many recreational beaches during the past summer. In order to aid in the identification of the sources of bacterial pollution, a need for a bacteriological study in the Humber River Basin was identified by the Water Quality Committee (WQC) of the Toronto Area Watershed Management Study (TAWMS). The bacteriological study, designated by WQC as Task 8B, was undertaken in partial fulfillment of the TAWMS overall goal which is as follows:

> To develop a comprehensive water management plan for the study area that would maintain or upgrade water quality in the upper stream reaches, and upgrade stream and near-shore lake water quality in urbanizing and existing urban areas, to make these waters more suitable for aquatic life and other beneficial uses.

The objective of Task 8B Study are as follows:

1. To establish the bacteriological quality of the Humber River relative to applicable MOE Provincial Water Quality Objectives.

2. To identify the origins of fecal contamination in the Humber River.

1.2 Study Area and Sampling Sites

The Task 8B study area includes the Humber River basin within the Metropolitan Toronto boundaries. The watercourses include the Humber River from Steeles Avenue to Lakeshore Boulevard and the Black Creek from Lawrence Avenue to its confluence with the Humber River near Scarlett Road (Figure 1.1).

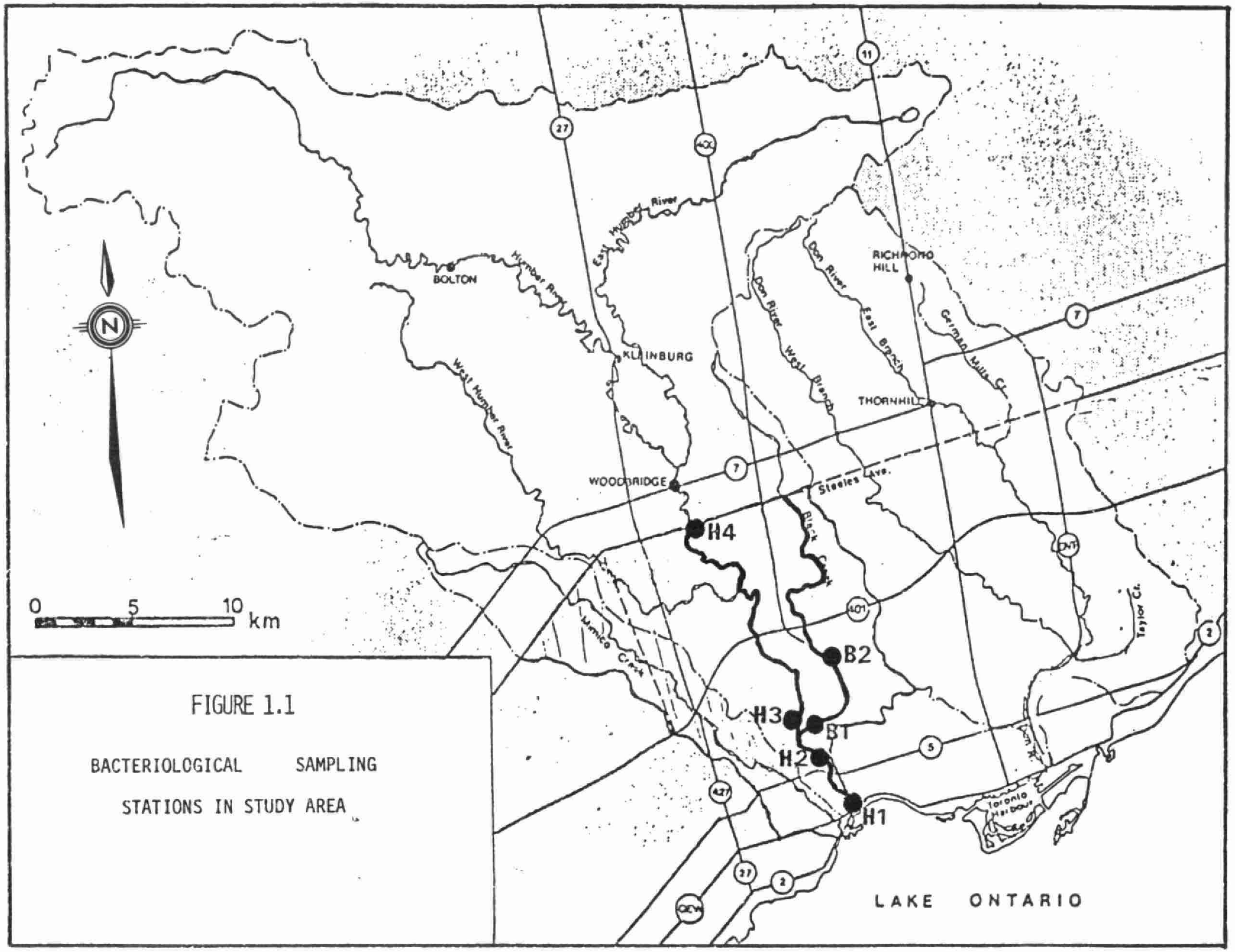


FIGURE 1.1

BACTERIOLOGICAL SAMPLING STATIONS IN STUDY AREA

There are six sampling sites at which the bacteriological water quality is monitored: four on the Humber River and two on the Black Creek. These stations are shown on the map in Figure 1.1. Detailed site maps for these six sampling stations are presented in Figures 1.2(a) - (f). The locations of sampling sites, station designations and other salient features are presented in Table 1.1.

1.3 Bacteriological Parameters

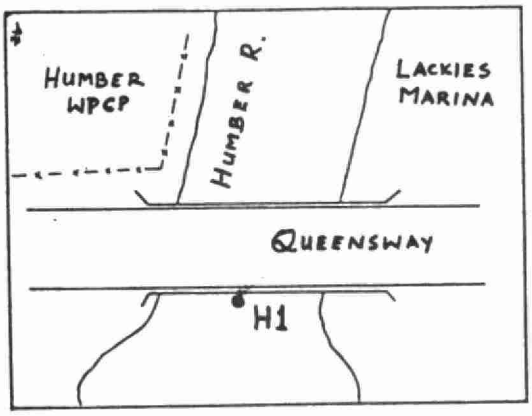
The bacteriological parameters considered in this recreational water quality study are as follows:

Fecal coliforms (FC)
Fecal streptococcus (FS)
Enterococcus
Escherichia coli (E.coli)
Pseudomonas aeruginosa (P.aeruginosa)

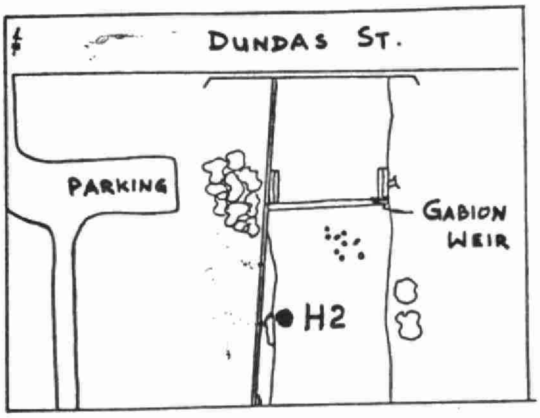
Several other types of bacteria have also been found in recreational waters. Pitt (1982) has presented a review of the types of bacteria found in stormwaters and their sanitary significance. Brief descriptions of the above five types of bacteria are presented in the following paragraphs (MOE, 1978; APHA, 1980).

The fecal coliform (FC) group is an indicator of the bacteriological water quality. The densities of FC in water are related quantitatively to the presence of sewage or fecal matter, and hence, to the potential to cause disease from the pathogens that may be present therein. This group includes the genera Escherichia, Klebsiella, Enterobacter and Citrobacter. The latter two of the FC group can also grow in nutrient-enriched environments. Recent epidemiological studies of swimming-related illness at selected conservation areas in Ontario have shown that FC density could be qualitatively related to the illness rate (Seyfried and Brown, 1983). However, similar studies in the United States have shown that FC density is very poorly correlated with illness (Dufour 1983).

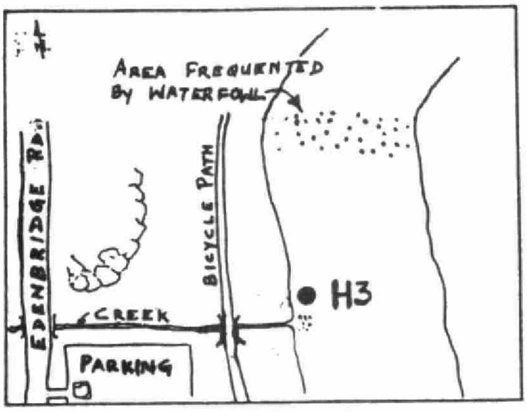
The fecal streptococcus (FS) group is another indicator of bacteriological water quality. This group implies the species and subspecies listed in Table 1.2 (APHA, 1980). The predominant sources of each species are also presented in Table 1.2.



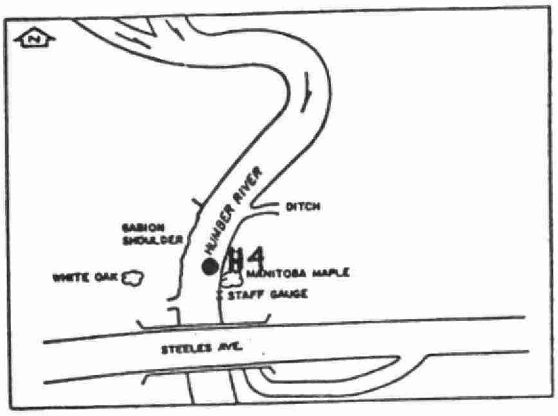
(a) Humber R. @ Lakeshore Blvd.



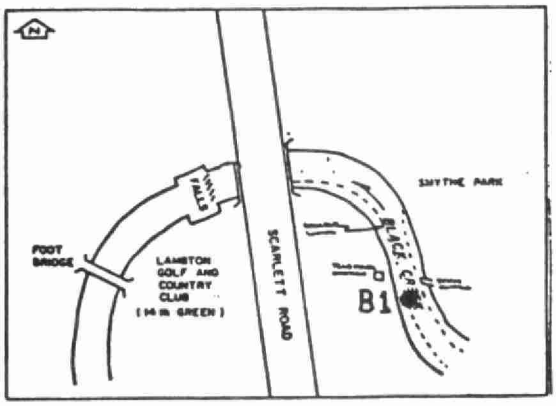
(b) Humber R. @ Dundas St.



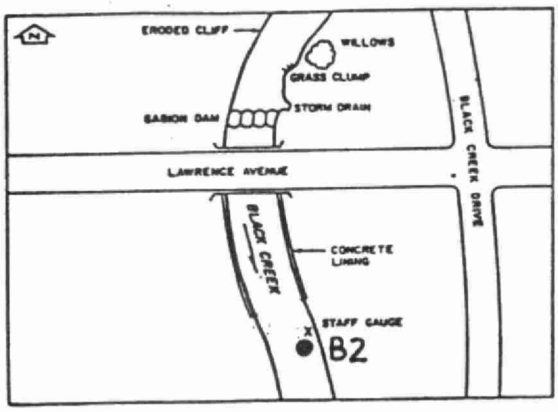
(c) Humber R. @ James Gardens



(d) Humber R. @ Steeles Ave.



(e) Black Cr. @ Scarlett Rd.



(f) Black Cr. @ Lawrence Ave.

FIGURE 1.2 DETAILED SITE MAPS

TABLE 1.1

BACTERIOLOGICAL STUDY - SAMPLING STATIONS

Serial No.	Location	Station Designation	Remarks
1.	Humber River at Lakeshore Blvd.	H1	Sampled off the Queens-way Bridge (Figure 1.2a)
2.	Humber River at Dundas Street	H2	Sampled about 50 meters downstream from the bridge (Figure 1.2b)
3.	Humber River at James Gardens	H3	Sampled just upstream of a creek inflow, near the northern end (Figure 1.2c)
4.	Humber River at Steeles Avenue	H4	Sampled near staff gauge upstream of the bridge (Figure 1.2d)
5.	Black Creek Scarlett Road	B1	Sampled near streamflow gauging station, about 20 meters upstream of bridge location (Figure 1.2e)
6.	Black Creek at Lawrence Avenue	B2	Sampled at staff gauge, about 100 meters downstream from the bridge (Figure 1.2f)

TABLE 1.2

FECAL STREPTOCOCCUS GROUP OF BACTERIA

Species	Predominant Source
S. faecalis	Human and animal intestines.
S. faecalis subspecies *liquefaciens*	Human and animal intestines, insects, vegetation and certain soils.
S. faecalis subspecies *zymogenes*	Human and animal intestines.
S. faecium	Human and animal intestines.
S. faecium variety *casseliflavis*	Vegetation, soils and some animal intestines.
S.durans	Human and animal intestines.
S.bovis	Primarily excrement of non-human, warm-blooded animals, in particular, ruminants.
S.equinus	Excrement of non-human, warm-blooded animals.
S.avium	Feces of humans and other warm-blooded animals, particularly fowl.

The FS group bacteria are normally present in the intestines of man and animals. Certain FS bacteria are host-specific. The survival of the FS group in the environment outside the animal host is dependent on the individual species of the group, thus limiting their use as indicators. However, the FS densities can be used in combination with the FC densities to provide more specific information about pollution sources as outlined later in Section 1.4.

The Enterococcus group of bacteria includes the following species of the FS group:

S.faecalis, S.faecalis subsp. liquefaciens, S.durans,
S.faecalis subsp. zymogenes, S.faecium, and
S.faecium subsp. casseliflavis

Some recent epidemiological studies have shown that the Enterococcus group is a better indicator of recreational water quality than the FC group (Dufour 1982, 1983). This is based on correlations of swimming-related gastrointestinal illness to Enterococcus and FC densities.

Escherichia coli (E.coli) which belongs to the FC group of bacteria, can cause diarrhea. In recent epidemiological studies, a relationship between swimming-related gastrointestinal illness and E.coli densities has been observed (Dufour 1982, 1983).

P.aeruginosa is associated with eye, ear and skin infections (Burger, 1983; Seyfried and Fraser, 1978; Seyfried and Brown, 1983). Generally, the sources of these bacteria include humans and some animals, particularly those living in polluted environments (eg., gulls).

1.4 Ratios Between Fecal Coliform and Fecal Streptococcus Densities

Traditionally, the (FC/FS) ratios obtained by Geldreich and Kenner (1969) have been utilized to differentiate the possible sources of fecal contamination of stream waters. The (FC/FS) ratios in those studies, developed from estimated per capita contributions of FC and FS for animals, ranged from 0.1 to 0.6 for non-human warm-blooded animals and 4.4 for humans. Thus, a ratio greater than or equal to 4 was considered to indicate fecal contamination by human-origin waste sources, whereas a ratio less than 0.7 was related to non-human sources

of pollution. Ratios between 0.7 and 4 were considered to indicate fecal contamination from mixed human and animal waste sources. According to Geldreich and Kenner, these ratios tend to be less reliable when FS densities are below 100/100 mL. They also state that the ratios are more meaningful for samples taken near wastewater sources in a receiving stream. A preliminary evaluation of the results of a recent MOE-sponsored research study, carried out by Seyfried and Harris at the University of Toronto, indicates that the (FC/FS) ratios for various fecal sources differ quite dramatically from those of Geldreich and Kenner (M. Young, MOE, Personal Communication, 1985). For the purposes of interpreting the bacteriological data gathered in the Humber River basin, the (FC/FS) ratios obtained in the MOE-sponsored study are summarized in Table 1.3. In general, these ratios are seen to be higher than those of Geldreich and Kenner (1969). Changes in microbiological laboratory measurement techniques are probably the main reason for the differences. The characteristics of food consumed by non-human animals may be another reason for the dramatic differences.

The ratios for human as well as dog, duck and gull fecal matter are much larger than those reported by Geldreich and Kenner (1969). Although the ratios differ from one fecal source to another, it is difficult and unwise to utilize these ratios for a precise identification of the waste sources (especially human waste source). The same argument applies to the other (FC/FS) ratios summarized in Table 1.3. Therefore, for the sake of convenience the (FC/FS) ratios are designated as Human, Group I, Group II and Group III, as indicated in the table. The ratios for non-human animal waste sources are included in Groups I, II and III. This designation is utilized to interpret the bacteriological study data in this report.

The above discussion of (FC/FS) ratios is usually applicable to samples taken close to sources of fecal pollution, as stated earlier. For sampling done at farther locations, Feachem (1975) states that the change in the ratios can be used as a guide to indicate the possible fecal source. According to Feachem, when a series of FC and FS densities are obtained through time, a predominantly human waste source of pollution should exhibit an initially high FC/FS ratio which should then fall, whereas a non-human source should exhibit an initially low ratio which should subsequently rise. The ratios of Geldreich and Kenner (1969) were utilized in the analysis of Feachem (1975). The recent (FC/FS) ratios given in Table 1.3 have not been applied to test Feachem's hypothesis. However, stress tests conducted at the University of

TABLE 1.3

(FC/FS) Ratios in Warm-Blooded Animal Feces

FECAL SOURCE	RATIO (FC/FS)	GROUP NUMBER
Human	10+ to 20+	--
Gull	10+ to 20+	I
Duck	10+ to 20+	I
Dog	10+ to 20+	I
Pigeons		II
Muskrat	About 1	II
Chicken	to	II
Pig	Less Than 5	II
Cat		II
Goose		III
Racoon	Less Than 0.5	III
Cow		III

Source: MOE-Sponsored Research Study - Preliminary Results

Toronto indicated a dramatic decrease in the human source FC/FS ratio to less than one, while the ratios for non-human sources varied (up or down) or remained constant. These results further demonstrate the need to be close to the source in utilizing the FC/FS ratios to identify fecal pollution of recent origin (Personal Communications, M. Young, MOE).

1.5 Recreational Water Quality Objectives

The provincial water quality objectives (PWQO) for recreational waters (MOE 1978) state that a potential health hazard exists if the fecal coliform geometric mean density for a series of water samples exceeds 100/100 mL. Although there are no PWQO, in quantitative terms, for the other bacterial parameters considered in this TAWMS-WQC Task 8B Study, the PWQO clearly state that when pathogenic organisms (eg. P.aeruginosa, Salmonella typhii and polio virus) can be enumerated and frequently isolated from water, a potential health hazard exists.

The recently published Health and Welfare Canada (1983) guidelines for recreational water quality state that the geometric means of not less than five samples taken over a 30-day period should be less than 200 FC/100 mL and that resampling should be performed when any sample density exceeds 400 FC/100 mL.

Recent epidemiological studies of swimming-associated illness and water quality has led to the quantification of public health risks associated with various bacterial densities for Enterococcus, E.coli and P.aeruginosa (Dufour, 1982; and 1983; IJC, 1983). For Enterococci, mean densities of about 1 count per 100 mL for undetectable and 10/100 mL for 1% swimming-associated gastrointestinal illness rates were identified (Cabelli, 1980; Miescier and Cabelli, 1982). The IJC recommended objectives for these microbiological indicators of fresh recreational water quality are as follows (IJC, 1983):

> For the protection of human recreational users of nearshore waters from gastrointestinal (GI) illnesses, the Enterococcus (mE) geometric mean level should not exceed 11/100 mL; similarly the Escherichia coli (mTEC) geometric mean level should not exceed 23/100 mL. Mean levels should be monitored by analyzing a minimum of five samples from one location collected over a four-week period.

For the protection of human recreational users of nearshore waters from ear infections, no more than twenty-five percent (25%) of the analyses should have levels of Pseudomonas aeruginosa (mPA method) greater than 10 P.aeruginosa per 100 mL.

Note: Under these conditions, the mean or median level of P.aeruginosa will usually be less than 1 per 100 mL.

The recreational water quality objectives as per the MOE PWQO for fecal coliforms and the IJC recommendations for Enterococcus, E.coli and P.aeruginosa will be utilized for a broader interpretation of the bacteriological data gathered in this study. These objectives are summarized in Table 1.4.

The foregoing provincial and IJC recommended objectives refer to the geometric mean of a minimum number of samples taken over a four-week period at a location. The samples collected during dry weather can be analyzed according to this procedure. However, the bacterial densities at an instream station due to a wet weather event will be generally higher than the background values for some duration of time. Therefore, a question arises as to what is a representative wet weather bacterial density that should be utilized in calculating the geometric mean bacterial density for the four week period. Since the objectives do not provide any guidance on this aspect, the dry and wet weather data will be considered separately in the analyses related to comparison between measurements and objectives. It is recommended that the MOE undertake studies for evaluating the effect of wet weather event bacterial densities in interpreting the objectives.

1.6 Study Components

The various components of this study are as follows:

- A field program to collect water quality data at the various sites during both dry and wet weather periods.

- Collection of meteorological and streamflow data.

- Analyses of dry and wet weather data and interpretation.

TABLE 1.4

RECREATIONAL WATER QUALITY OBJECTIVES

Bacteriological Parameter	Objectives	Remarks
Fecal coliform (FC)	100/100 mL*	Geometric mean of a minimum of ten samples from one location collected over a 30 - day period.
Enterococcus	11/100 mL**	Geometric mean of a minimum of five samples from one location collected over a 30 - day period.
E. coli	23/100 mL**	Same as above.
P. aeruginosa	10/100 mL** in 25% of the analysis	Same as above.

* MOE provincial water quality objective (PWQO)
** IJC recommendations

- Assessment of dry weather outfall bacteriological quality as a source of instream contamination.

- Identification of bacteriological quality and problem areas using data collected in the Fall 1982 and July 1983 TAWMS surveys.

- Attempts to identify the sources of fecal contamination.

- Identification of bacteriological trends in the dry and wet weather runoff events.

2 DATA COLLECTION ASPECTS

2.1 General Sampling Procedures

In general, the sampling procedures stated in the MOE publication "Outline of Analytical Methods" (MOE, 1981) and the Standard Methods (APHA, 1980) were followed in collecting the water samples for bacteriological analyses during the dry and wet weather surveys.

All field personnel were instructed on sample collection and preservation procedures. The field personnel were informed of the safety procedures that should be followed in the field in handling equipment and during sampling. The personnel visited the study area to become familiar with the field conditions at each site.

A sampling pole was utilized to collect the water samples at each station, except Station H1 where a specially designed wire-mesh sample holder (with the bottle top protruding above the wire-mesh) was utilized to sample off the Queensway Bridge. The samples were collected in sterile sampling bottles provided by the MOE Laboratory, Rexdale. Sufficient sample volume (2 bottles, each of 180 mL capacity), required to analyze for the five bacterial parameters listed in Section 1.3, was collected at each site.

The samples from each site were collected at the same location every time the site was sampled; the sampling location was in an area with good currents. Each sample bottle was identified with the stream station number, date and time of collection. The bottles were lowered below the surface of water with the bottle mouth facing the current and held there until bubbles stopped appearing at the surface. The bottles were removed from water, water level adjusted to the top of the label, capped and unclamped from the sample holder or the pole. They were then placed in a cooler for preservation. The sample bottles, accompanied by the MOE laboratory sample submission sheets, were delivered to the MOE laboratory at Rexdale after the completion of sampling at all six stations during dry weather and two or three times during each wet weather event.

At the time of sample collection at each site, various details were recorded on field data sheets. These included date of sampling, weather conditions, visual water quality conditions at the site, time of sampling, water level,

water temperature, conductivity, as well as the number and type of water fowl, if any. The MOE bacteriology laboratory staff were informed at the time of each survey so as to permit necessary preparations for the bacteriological analyses to commence as soon as the samples were received.

2.2 Field Studies

2.2.1 Dry Weather Surveys

Sampling stations for the dry weather surveys included the four stations, H1 to H4, on the Humber River, and the two stations, B1 and B2, on the Black Creek. The sites were sampled on ten separate occasions during the period September 12 to October 25, 1983. Although the dry weather sampling was to have been completed in a period of 30 days, the frequent occurrence of rainfall events in some of the weeks made it impossible to comply with this requirement. Generally, each dry weather survey was carried out following at least a 48-hour continuous non-wet period.

On one occasion, sampling was done on a Sunday (September 15, 1985) and all other dry weather surveys were conducted on a weekday during Monday through Thursday. This sampling scheme was designed to permit laboratory bacteriological analyses within 24 hours of sample collection.

2.2.2 Wet Weather Surveys

The sampling sites for the wet weather monitoring included four stations - Stations H2 and H3 on the Humber River, and Stations B1 and B2 on the Black Creek. Two events were monitored: first event during October 3 to 4, 1983; and second event during November 15 to 17, 1983.

The weather forecast information from the AES Weather Office and the early storm warning system of the Metropolitan Toronto and Region Conservation Authority were utilized to select the events to be monitored. This information was utilized to mobilize the field crew and for other preparations. At each site, prior to the storm event, a water sample was collected and water temperature, specific conductance and water level measurements were taken to define the pre-event (or background) conditions. Sampling for the first event began at about 20:30 hours (EDT) on October 3, 1983 and ended at about 14:30 hours (EDT) on October 4, 1983. The second

event sampling began at about 13:00 hours (EDT) on November 15, 1983 and continued until approximately 13:30 hours (EDT) on November 16, 1983. At this time, the water levels in the streams were still quite high, but the conductivity levels remained fairly steady. (This was attributed to very high rainfall which occurred intermittently). An additional sampling run was carried out on the morning of November 17, 1983, as part of the second wet weather event.

The conductivity and water level measurements were utilized as relative indicators of water quality during the wet weather sampling. Specifically, this information was used to select the samples collected during the initial "first flush" period for bacteriological analyses, as well as to define approximate pre-event conditions.

Black Creek Sites: Water samples at each of the two Black Creek sites, where the effect of a runoff event was expected to last 6 to 8 hours, were collected at about 1/2 to 1-hour intervals. Each time a water sample was collected, specific conductance, water level and temperature were also measured.

During the October event, fourteen (14) samples were collected from each station on the Black Creek, whereas during the November event, sixteen (16) samples per station were collected.

Humber River Sites: The effect of a runoff event at these sites was expected to last 24 to 48 hours, and hence, specific conductance, temperature and water level measurements, and water sampling was carried out at about 3/4 to 3-hour intervals at each site.

The number of samples collected from each Humber River station was eight (8) during the October event and ten (10) during the November event.

2.3 Laboratory Analytical Procedures

The bacteriological analyses procedures for FC, FS and *P.aeruginosa* are described in the MOE publication "Outline of Analytical Methods" (MOE, 1981). Enterococcus and *E.coli* bacteria were analyzed by the methods utilized for special projects at the MOE Microbiology Laboratory. Brief descriptions of the laboratory methods are presented below.

Fecal coliforms: Analyses for fecal coliforms are by membrane filtration. The membrane is placed on a petri dish containing mTEC agar and incubated to allow a gradual increase to 44.5 ± 0.5°C over a four hour period. The total incubation time is 22 ± 1 hours. After incubation, the number of fecal coliform colonies are determined with a stereoscopic microscope at 10X magnification. All yellow, yellow-brown and yellow-green colonies are counted.

Fecal streptococcus: Analysis for FS is by membrane filtration (HAMES). The membrane is placed on m-Enterococcus agar (Difco) and incubated at 35.0 ± 0.5°C for 48 ± 3 hours. Using a stereoscopic microscope (10X), all colonies that are red, maroon or pink are counted as fecal streptococci.

Enterococcus: Analysis for the enterococcus group is by membrane filtration. The membrane is placed on mE agar (see Appendix D) and incubated at 41.0 ± 0.5°C for 48 ± 2 hours. Using a stereoscopic microscope (10X), all colonies that are gray with a red centre and blue halo, are counted as Enterococci. [Note: The incubation time is usually 23 ± 1 hours. The larger time was found to improve the enumeration (Personal Communication, M. Young, MOE)].

E.coli: Analysis for E.coli requires filtration of an appropriate volume or dilution of the sample and incubation on mTEC-IG agar (see Appendix D). The plates are incubated to allow a gradual increase to 44.5 ± 0.5°C over approximately 4 hours. Total incubation time is 22 ± 1 hours. Using a stereoscopic microscope (10X), all colonies that remain yellow, yellow-green or yellow-brown, are counted as E.coli.

P.aeruginosa: An appropriate volume or dilution of the sample is filtered through a 0.45 μ membrane filter and incubated in mPA agar at 41.5 ± 0.5°C for 48 ± 2 hours. Using a stereoscopic microscope (10X), all tan to dark-brown or black colonies are counted as P.aeruginosa.

2.4 Field Survey Data

2.4.1 Dry Weather Survey Data

The data from all the dry weather surveys for each station, which were recorded on field data sheets and bacteriological laboratory reports, were summarized in tabular form. The data summaries for each of the six stations (H1 to H4 and B1 to B2) are presented in Tables A1 to A6 in Appendix A.

2.4.2 Wet Weather Survey Data

The wet weather survey data summaries are also presented in Appendix A. Tables A7 to A10 show the data summaries for each of the four stations (H2, H3, B1 and B2) for the rainfall event of October 3 to 4, 1983 and Tables A11 to A14 present the data summaries for each station for the event monitored during November 15 to 17, 1983.

2.5 Meteorological and Streamflow Data

2.5.1 Air Temperature and Precipitation

Table 2.1 shows the meteorological stations for which the air temperature and precipitation data were obtained. The type of data recorded at each station and the duration for which the data were available are also shown in the table.

Daily summaries of meteorological data are presented in Table B1 in Appendix B. Also, for the two wet weather survey periods (i.e., October 3 to 4, 1983 and November 15 to 17, 1983), detailed precipitation data have been presented in Table B2 in Appendix B.

2.5.2 Streamflow Data

The average daily streamflows for the Humber River at Weston Road (Streamflow gauging station 02HC003) and Black Creek at Scarlett Road (Streamflow gauging station 02HC027) were determined from the streamflow monitoring records. The daily streamflows for these two stations are presented in Table B3 in Appendix B for the period September - October 1983.

Detailed streamflow information was obtained from the monitoring records for the October 3 to 4 and November 15 to 17, 1983 wet weather events. These data are presented in Table B4 in Appendix B, as well as in Tables A7 to A14 in Appendix A along with the bacteriological and other data summaries.

2.6 Data From Previous Studies

The following bacteriological and other relevant data, gathered during routine monitoring and previous surveys, were provided by the MOE staff:

TABLE 2.1

METEOROLOGICAL RECORDS

STATION	AIR TEMPERATURE	PRECIPITATION
KEELE - FINCH	NOT RECORDED	AUG 3-30 & OCT 3-22, 1983
ISLAND AIRPORT	AUG 1 - OCT 31, 1983	AUG 1 - OCT 31, 1983
BLOOR STREET	AUG 1 - OCT 31, 1983	AUG 1 - OCT 31, 1983
AMESBURY PARK	NOT RECORDED	AUG 3 - OCT 5, 1983
BOLTON WPCP	AUG 1 - SEPT 30, 1983	AUG 1 - SEPT 21, 1983
TORONTO INTERNATIONAL AIRPORT	AUG 1 - SEPT 31, 1983	AUG 1 - SEPT 31, 1983

1. Historical water quality monitoring data for the years 1977 to 1981.

2. TAWMS Fall 1982 Dry and Wet Weather and July 1983 Dry Weather Survey Data.

3. Dry Weather Outfall Study Data collected for the TAWMS Pollution Control Committee (Gartner Lee Associates Ltd., 1983).

Summaries of these data are presented in Tables C1 - C3 in Appendix C. These data will be utilized to evaluate bacteriological trends, potential sources of contamination of stream waters and other aspects of this study.

3 DATA ANALYSES AND INTERPRETATION

3.1 Dry Weather Survey Results

The air temperatures during August - October 1983, based on the Toronto Bloor Street Meteorological Station records, were as follows:

Month	Air Temperature (°C) Mean	Range
August 1983	22.4	18.4 - 26.4
September 1983	18.2	13.8 - 22.6
October 1983	10.9	7.4 - 14.3

The observed ranges of water temperature, discharge and conductivity at various sampling stations are summarized in Table 3.1.

The conductivity values observed at the four Humber River stations are typical of those in Southern Ontario streams and rivers. But, at the two Black Creek stations, the observed conductivity values are about twice those in the Humber River, and are very close to those observed in treated sewage effluents (eg., conventional activated sludge plant effluents).

The dry weather survey bacteriological data summarized in Tables A1 - A6 (Appendix A) were utilized to compute the geometric mean densities of various bacterial parameters for each station. In some cases, the laboratory analytical results were reported as "less than" and "approximate" values. The latter were considered to be sufficiently accurate for data analyses purposes. In the case of "less than" values, a constant value (X_r) was added to each value and an apparent geometric mean (X'_g) was obtained. Then, the geometric mean (X_g) was computed from $X_g = X'_g - X_r$.

An example showing the computational details is presented in Appendix E. (Note: The same procedure has been utilized to compute the geometric mean bacterial densities for the two wet weather surveys).

TABLE 3.1

OBSERVED RANGE OF WATER TEMPERATURE, DISCHARGE AND CONDUCTIVITY - DRY WEATHER RESULTS

Station	Water Temperature °C	Discharge (m^3/s)	Conductivity (umhos/cm)
H1	9-18°	-	390-550
H2	8-19°	-	410-525
H3	9-18°	-	390-450
H4	8-18°	0.947-2.924*	360-450
B1	11-19°	0.062-0.296	900-1400
B2	10-18°	0.045-0.130	730-1000

* approximated by summing upstream flow at Elder Mills and Pine Grove (East Humber)

The geometric mean densities of the five bacteriological parameters at each station are presented in Table 3.2. These results indicate that, in general, the densities at the two Black Creek stations, B1 and B2, are at least an order of magnitude higher than those of the Humber River stations. The ratios, FC/FS, are also given in the table.

The dry weather geometric mean densities of FC exceed 100/100 mL at all six stations, and hence, are in noncompliance with the objective of 100/100 mL. The densities are seen to increase from the upstream to the downstream portions; however, there is a slight decline at Station H1 (Humber at Lakeshore) probably due to dilution with lake water. The geometric mean densities of FC in Black Creek increase about 3.5 times from Lawrence Avenue (Station B2) to Scarlett Road (Station B1).

The fecal streptococcus (FS) densities range from 80 - 172.3/100 mL in the Humber River, increasing from Station H4 to Station H2 and declining slightly at Station H1. This pattern is very similar to that of FC. The densities of FS in the two Black Creek Stations are about the same, but higher than those in the Humber River.

The FC/FS ratios in Table 3.2 have values of 8.46 in Black Creek at Scarlett (Station B1) and 7.71 in Humber River at Lakeshore (Station H1), indicating the possible presence of a combination of Group I and Group II fecal sources close to the stations or a mixture of human and non-human fecal sources located further upstream. There are combined sewer overflow locations upstream of these two stations (see Section 3.6). Therefore, the FC/FS ratios at Stations B1 and H1 may be indicative of human and Group I animal waste sources located upstream from these stations. There are no fecal sources due to gulls and ducks in Black Creek above Station B1; thus, the fecal contamination in Black Creek could be due to human and dog waste sources. On the other hand, FC/FS ratios at Station H1 in the Humber River could be due to human and Group I (dog, duck, gull) waste sources. The ratios at the other four stations range from 1.43 to 3.64 which are indicative of the possible presence of Group II (i.e., non-human) waste sources near these locations or other waste sources located farther upstream (eg., human and Group I).

In the Humber River, the FC/FS ratios vary from 1.43 to 7.71, exhibiting an increasing trend from upstream (Station H4) to the downstream (Station H1) boundary; a similar trend of the ratios is evident in Black Creek as well

TABLE 3.2
GEOMETRIC MEAN BACTERIAL DENSITIES FOR
DRY WEATHER SURVEYS - SEPT. 12 - OCT. 25, 1983

STATION	PARAMETER	NDT*	GEO.MEAN**	FC/FS
H1	FECAL COLIFORM	10	617.2	7.71
	ESCHERICHIA COLI	10	431.6	
	FECAL STREPTOCOCCUS	10	80.0	
	ENTEROCOCCUS	10	12.2	
	P. AERUGINOSA	10	9.0	
H2	FECAL COLIFORM	10	627.3	3.64
	ESCHERICHIA COLI	10	411.3	
	FECAL STREPTOCOCCUS	10	172.3	
	ENTEROCOCCUS	10	11.7	
	P. AERUGINOSA	10	5.7	
H3	FECAL COLIFORM	10	403.9	3.11
	ESCHERICHIA COLI	10	292.9	
	FECAL STREPTOCOCCUS	10	130.0	
	ENTEROCOCCUS	10	9.0	
	P. AERUGINOSA	10	5.0	
H4	FECAL COLIFORM	10	126.6	1.43
	ESCHERICHIA COLI	10	67.7	
	FECAL STREPTOCOCCUS	10	88.5	
	ENTEROCOCCUS	10	2.3	
	P. AERUGINOSA	10	1.5	
B1	FECAL COLIFORM	10	4548.2	8.46
	ESCHERICHIA COLI	10	2782.5	
	FECAL STREPTOCOCCUS	10	537.7	
	ENTEROCOCCUS	10	86.7	
	P. AERUGINOSA	10	87.9	
B2	FECAL COLIFORM	10	1296.1	2.44
	ESCHERICHIA COLI	10	1048.7	
	FECAL STREPTOCOCCUS	10	530.3	
	ENTEROCOCCUS	10	35.5	
	P. AERUGINOSA	10	94.8	

*NDT: No. of data

**GEO.MEAN: Geometric mean density(counts/100mL)

(2.44 at Station B2 to 8.46 at Station B1). This trend could be indicative of fecal pollution from non-human waste sources located near the upstream boundaries (according to Feachem's hypothesis). However, the observed increasing trend may be due to the presence of active outfalls along the water courses thus making it difficult to suggest that the non-human waste sources are the only cause of the variations in FC/FS ratios.

Enterococci geometric mean densities exceed the objective of 11/100 mL at Stations H1 and H2 in the Humber River and at Stations B1 and B2 in the Black Creek. The densities increase from the uppermost stations towards the downstream stations in both water courses, indicating an increase in recent ("fresh") fecal matter.

The geometric mean densities of E.coli are in noncompliance with the objective of 23/100 mL at all six stations. There is an increase in the densities of E.coli from Station H4 to H1 in the Humber River, and from Station B2 to Station B1 in the Black Creek. This trend is similar to that for the enterococcus group, which tends to support increase of recent fecal matter.

P.aeruginosa densities are seen to increase from Station H4 to Station H1, but decline slightly from Station B2 to B1 in the Black Creek. The increases in the Humber River could signify increased human waste input and/or increased "sewer" inputs. As per the objectives, the P.aeruginosa geometric mean density should not exceed 10/100 mL in more than 25% of the samples from the same location. An analysis of the data presented in Tables A1 - A6 indicated that the objective was met at stations H2 and H4 on the Humber River, but, the remaining four stations were in noncompliance (see Table 3.3).

The percentages of the observed dry weather bacterial densities that were in noncompliance with the appropriate objectives as stated in Table 1.4, were calculated for each station. The results are summarized in Table 3.3. The percentages of noncompliance for fecal coliforms and E.coli are the same (100%) at all stations except Station H4. The results for Black Creek at Scarlett Road (Station B1) show 100% noncompliance for FC, Enterococci, E.coli and P.aeruginosa; at Station B2, a similar result is seen except for Enterococci.

TABLE 3.3

PERCENTAGE OF DRY WEATHER BACTERIAL DENSITIES IN NONCOMPLIANCE WITH THE OBJECTIVES*

Station	Fecal Coliform	Entero-coccus	E. coli	P. aeruginosa
H1	100%	60%	100%	40%
H2	100%	70%	100%	20%
H3	100%	50%	100%	30%
H4	60%	10%	80%	0
B1	100%	100%	100%	100%
B2	100%	80%	100%	100%

* PWQO for FC and IJC recommended objectives for other parameters.

3.2 Wet Weather Survey Results

The rainfall data for the October event were available for all meteorological stations, except for the Bolton Station (see Appendix B). However, for the November event, the data were available from the Toronto International Airport Station only. Table 3.4 shows the total amounts and approximate durations of the rainfall for the two events at various meteorological stations. The approximate rainfall durations were: 3 hours for the October event and 24 hours for the November event. The average rainfall intensities for both events are about the same (1.3 mm/h); however, the intensities varied considerably within each event (see Appendix B).

The observed ranges of temperature and conductivity values at the four stations (i.e., H2, H3, B1 and B2) for the two wet weather events are presented in Table 3.5. The discharge values at the start and end of sampling periods, as well as the peak flows observed at Station B1 and B2 are also given in Table 3.5. Since the stage-discharge relationships for Stations H2 and H3 are not available, the values for these stations could not be obtained although the water levels have been monitored. Therefore, only the discharge values for the Humber River at Weston Road are presented in Table 3.5. The water levels were recorded at Stations H2 and H3 in order to gather information on relative changes in discharge during the wet weather events.

Figures 3.1 (a) to (d) show plots of bacterial densities and (FC/FS) ratios versus time at the stations H2, H3, B1 and B2, respectively, for the October event. The discharge versus time plots are also presented for those cases for which data are available. Figures 3.2 (a) to (d) show similar plots for the November wet weather event. In general, the bacterial densities during the wet weather events exceed the appropriate objectives given in Table 1.4.

The plots of FC/FS ratio versus time show an increasing trend at all four stations for the October event (see Figure 3.1). But, the November event results indicate that the ratios fluctuate, decreasing on an overall basis (see Figure 3.2).

The observed range of FC/FS ratios at various stations are summarized below. In general, these ratios are indicative of a mixture of human and non-human waste sources.

TABLE 3.4

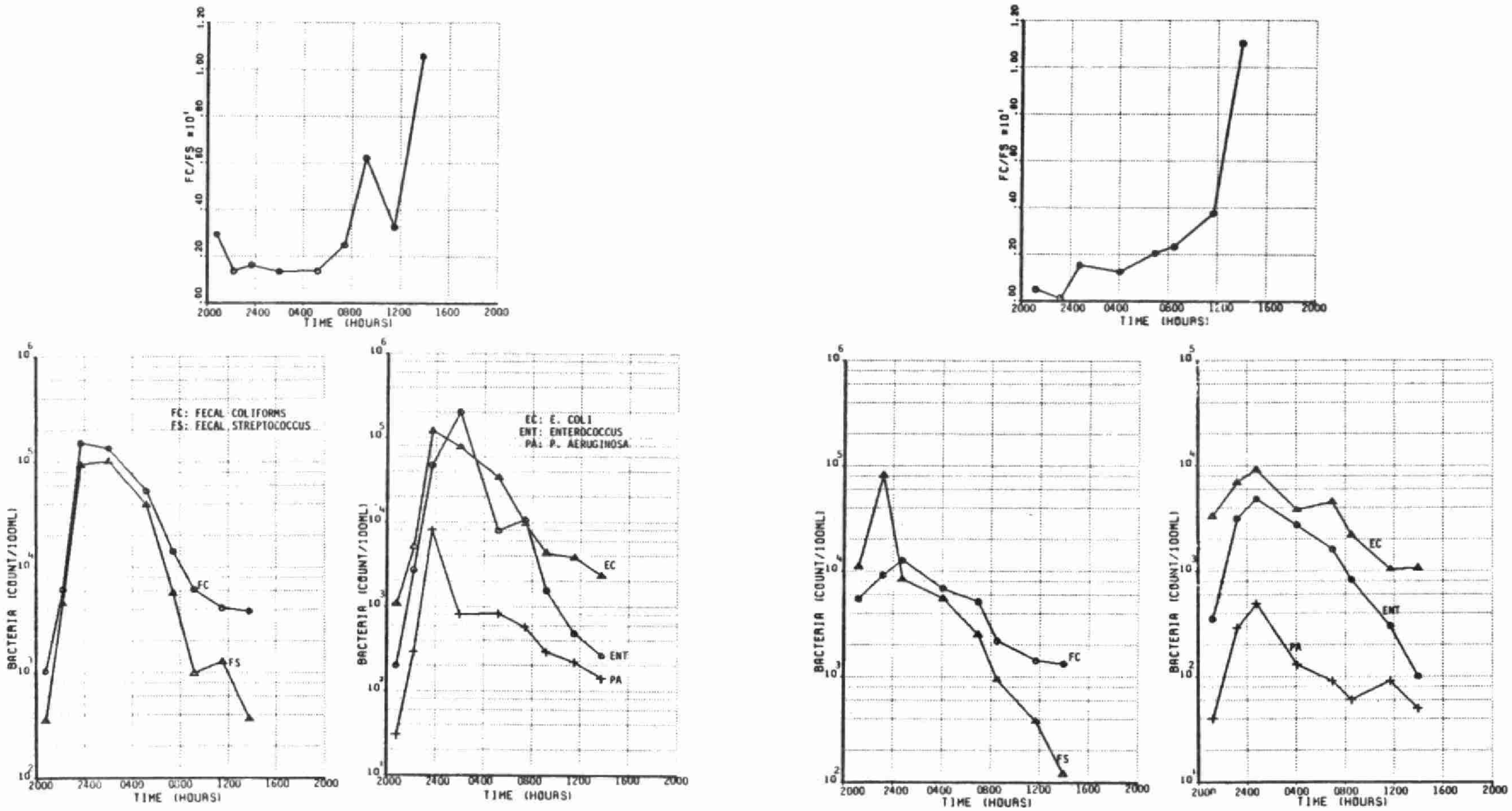
TOTAL AMOUNT AND DURATION OF RAINFALL FOR WET WEATHER EVENTS

Meteorological Station	October Event		November Event	
	Total Rainfall (mm)	Duration (hours)	Total Rainfall (mm)	Duration (hours)
Keele-Finch	4.0	3	-	-
Toronto-Bloor St.	4.8	2	-	-
Toronto Island Airport	4.0	2	-	-
Toronto International Airport	4.8	3	31.8	24
Amesbury Park	3.2	2	-	-

TABLE 3.5

TEMPERATURE, DISCHARGE AND CONDUCTIVITY - WET WEATHER EVENTS

WET WEATHER EVENT	STATION	TEMPERATURE RANGE (°C)	DISCHARGE (m3/s) Start	Peak	End	CONDUCTIVITY RANGE (umhos/cm)
Oct.3-4, 1983	Humber at Weston	-	1.67	2.23	1.79	-
	H2	18.0-20.0	-	-	-	500-600
	H3	17.5-20.0	-	-	-	440-480
	B1	17.5-20.0	0.373	1.270	0.230	720-1100
	B2	17.5-20.0	0.962	0.962	0.096	620-950
Nov.15-17, 1983	Humber at Weston	-	3.260	15.700	11.300	-
	H2	3.0- 7.0	-	-	-	240-450
	H3	3.0- 6.0	-	-	-	260-420
	B1	4.0- 7.0	0.650	10.600	1.270	200-1300
	B2	4.0- 7.0	0.27	7.128	0.706	225-2300

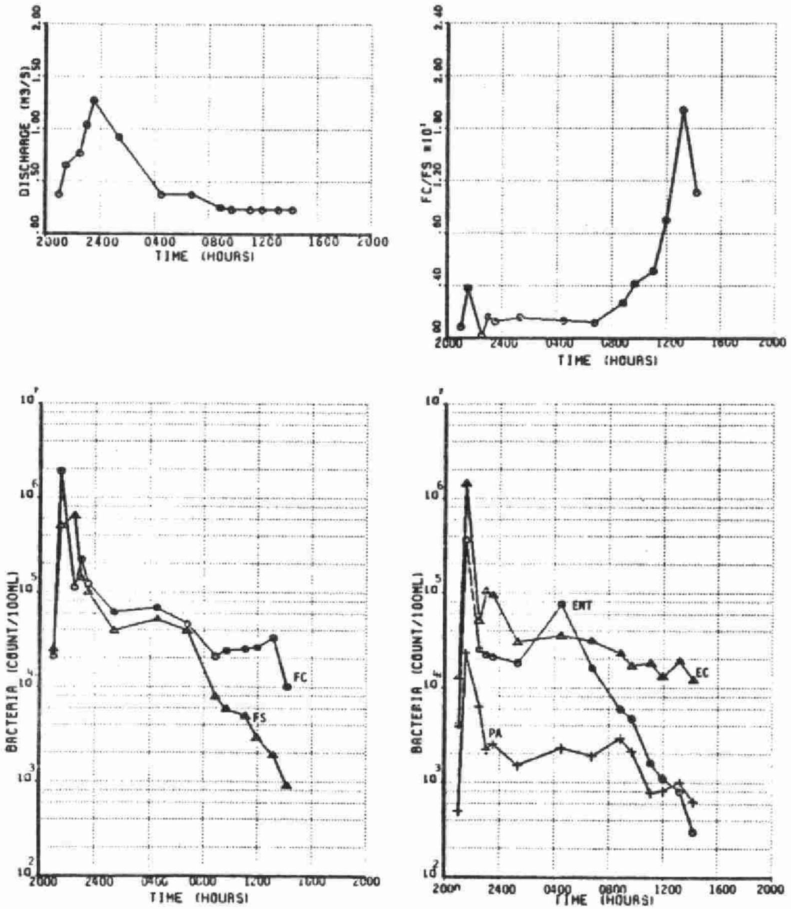


(a) Humber River @ Dundas St. West - Stn. H2

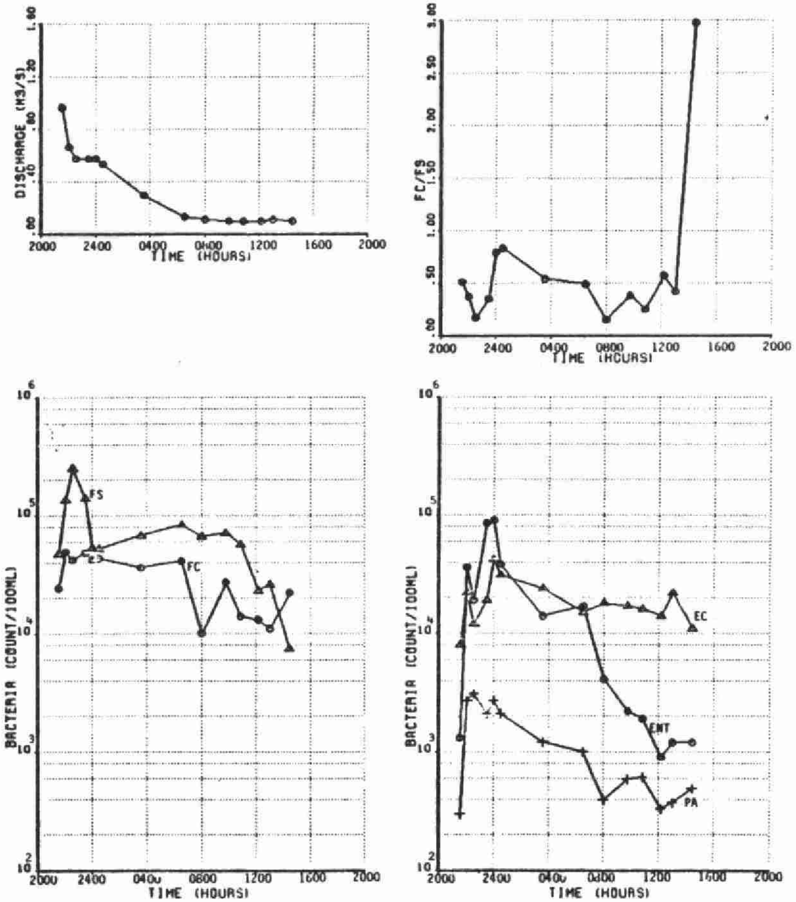
(b) Humber River @ James Gardens - Stn. H3

FIGURE 3.1 - DISCHARGE, BACTERIAL DENSITIES AND FC/FS RATIOS

VERSUS TIME - OCTOBER EVENT

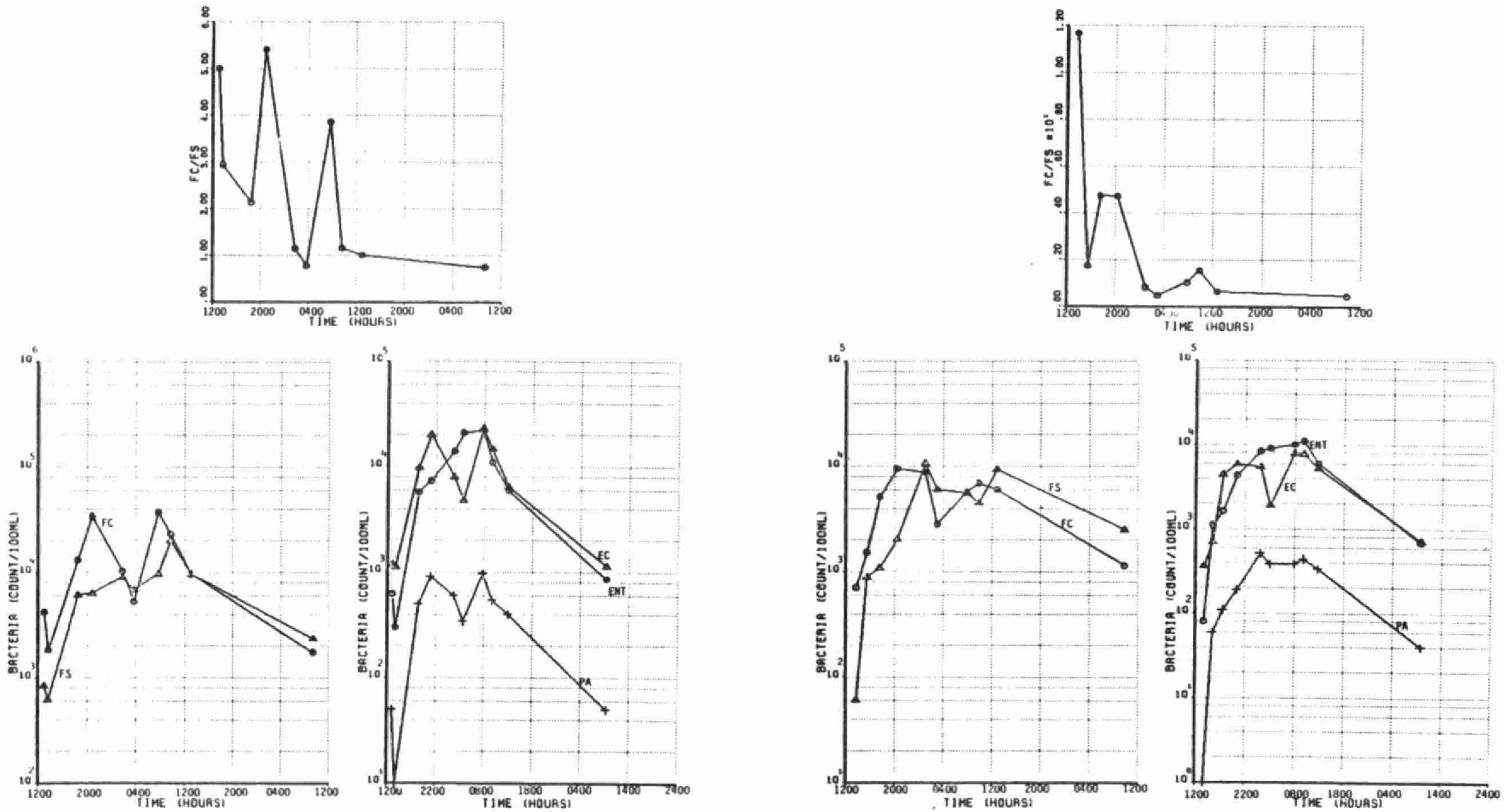


(c) Black Creek @ Scarlett Road - Stn. B1



(d) Black Creek @ Lawrence Avenue - Stn. B2

FIGURE 3.1 (Contd.)

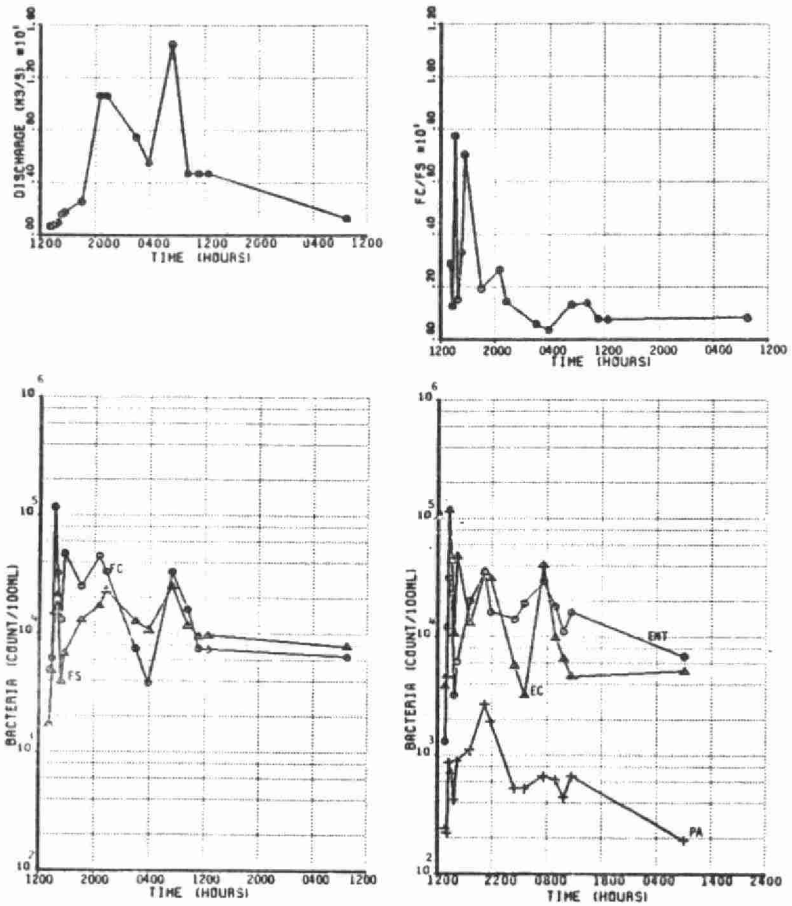


(a) Humber River @ Dundas St. West - Stn. H2

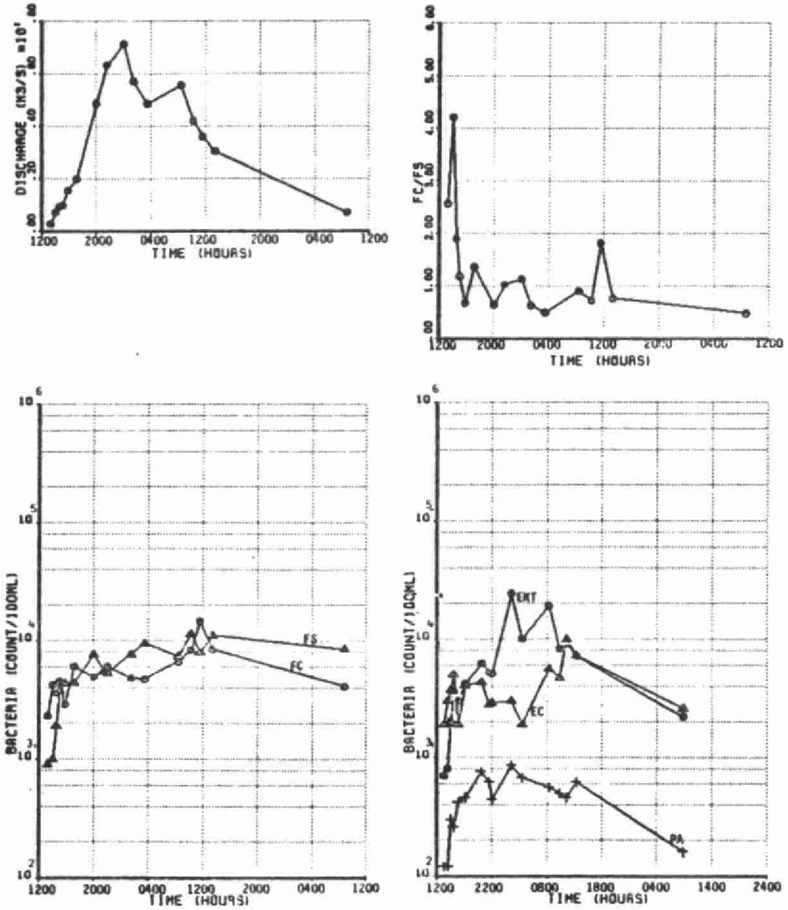
(b) Humber River @ James Gardens - Stn. H3

FIGURE 3.2 - DISCHARGE, BACTERIAL DENSITIES AND FC/FS RATIOS

VERSUS TIME - NOVEMBER EVENT



(c) Black Creek @ Scarlett Road - Stn. B1



(d) Black Creek @ Lawrence Avenue - Stn. B2

FIGURE 3.2 (Contd.)

STATION	RANGE OF (FC/FS) RATIOS	
	OCTOBER EVENT	NOVEMBER EVENT
H2	1.33 - 10.56	0.74 - 5.40
H3	0.11 - 11.00	0.46 - 11.67
B1	0.17 - 17.37	0.36 - 7.01
B2	0.17 - 2.97	0.48 - 4.20

The plots of bacterial density versus time exhibit the familiar "first flush" phenomenon. In Figure 3.2 (a), the densities of FC. E.coli and P.aeruginosa are seen to have two peaks (at 20:50 and 07:40 hours). These observations can be attributed to the effects of fresh fecal wastes which could have entered the stream from sewer overflows and other sources during this wet weather event. The FC/FS ratios in Figure 3.2 (a) exhibit two peaks coincident with the bacterial density peaks; but the ratios are in the range 4-5, indicating the possible presence of a mixture of waste sources. An examination of Figure 3.2 (c) shows somewhat similar observations of bacterial densities and FC/FS ratios.

The plots of bacterial density versus time (Figures 3.1 and 3.2) also indicate the occurrence of higher peak densities at Station H2 compared to Station H3 in the Humber River. Since Station H2 is located downstream of the Black Creek confluence, the increased peak values at Station H2 reflect the inputs from Black Creek. The bacterial densities of various parameters in Black Creek are also seen to have higher peaks at Station B1 compared to Station B2, indicating input of fresh fecal matter between these two stations, possibly from sewers.

The geometric mean bacterial densities as well as the minimum and maximum densities for the four stations are presented in Tables 3.6 and 3.7 for the October and November events, respectively. A comparison of these results with the appropriate bacteriological objectives (see Table 1.4), indicates that the geometric mean densities of all bacteriological parameters are in noncompliance with the objectives. However, the objectives in Table 1.4 refer to the average of a series of samples collected over a 30-day period, and hence, the comparative results should be considered in light of this limitation.

TABLE 3.6

BACTERIAL DENSITIES FOR THE
WET WEATHER EVENT OF OCTOBER 3 - 4, 1983

STATION	PARAMETER	NDT	DENSITY (/100 mL) GEO.MEAN	MAX.	MIN.
H2	FECAL COLIFORM	9	12760.2	150000	1030
	ESCHERICHIA COLI	9	9502.5	121000	1070
	FECAL STREPTOCOCCUS	9	4841.6	101000	350
	ENTEROCOCCUS	9	3513.9	200000	200
	P. AERUGINOSA	9	396.3	8100	30A
H3	FECAL COLIFORM	8	4148.6	12600	1320
	ESCHERICHIA COLI	8	3099.3	9100	1020
	FECAL STREPTOCOCCUS	8	2850.5	81000	120A
	ENTEROCOCCUS	8	928.7	4800	100A
	P. AERUGINOSA	8	107.6	490	40A
B1	FECAL COLIFORM	14	55253.0	1900000	10000
	ESCHERICHIA COLI	14	35993.6	1420000	12000
	FECAL STREPTOCOCCUS	14	22696.0	640000	900A
	ENTEROCOCCUS	14	7982.2	360000	300A
	P. AERUGINOSA	14	1867.3	23000	500A
B2	FECAL COLIFORM	14	26284.7	49000	10000
	ESCHERICHIA COLI	14	17765.4	42000	8000
	FECAL STREPTOCOCCUS	14	57148.8	250000	7400
	ENTEROCOCCUS	14	7359.1	90000	900A
	P. AERUGINOSA	14	917.9	3100	300

NDT - NO. OF DATA POINTS
A - APPROXIMATE RESULT

TABLE 3.7

BACTERIAL DENSITIES FOR THE
WET WEATHER EVENT OF NOVEMBER 15 - 17, 1983

			DENSITY (/100 mL)		
STATION	PARAMETER	NDT	GEO.MEAN	MAX.	MIN.
H2	FECAL COLIFORM	10	8746.9	37000	1740
	ESCHERICHIA COLI	10	5478.7	23000	1120
	FECAL STREPTOCOCCUS	10	4706.0	20000	620
	ENTEROCOCCUS	10	4411.8	22000	300
	P. AERUGINOSA	10	233.2	960	10A
H3	FECAL COLIFORM	10	3571.6	9500	700
	ESCHERICHIA COLI	10	2620.8	7900	360
	FECAL STREPTOCOCCUS	10	2310.6	10600	60A
	ENTEROCOCCUS	10	2699.5	11000	80A
	P. AERUGINOSA	10	149.5	520	10L
B1	FECAL COLIFORM	16	15640.0	116000	3800
	ESCHERICHIA COLI	16	13071.0	117000	3200
	FECAL STREPTOCOCCUS	16	9972.5	25000	1700
	ENTEROCOCCUS	16	12600.8	35000	1300
	P. AERUGINOSA	16	613.7	2700	190
B2	FECAL COLIFORM	16	5189.4	14500	2300
	ESCHERICHIA COLI	16	3597.1	10000	1900
	FECAL STREPTOCOCCUS	16	4931.6	11400	900A
	ENTEROCOCCUS	16	4634.2	24000	700A
	P. AERUGINOSA	16	393.9	860	120A

NDT - NO. OF DATA POINTS
A - APPROXIMATE RESULT
L - ACTUAL RESULT IS LESS THAN THE REPORTED VALUE

Generally, the two Black Creek Stations have higher geometric mean bacterial densities in comparison to the two Humber River Stations. Also, the geometric mean densities of various parameters are seen to increase from the upstream stations to the downstream ones in both water courses, with the exception of fecal streptococci which decreases from Station B2 to Station B1 in the October event. Thus, the overall effect of each wet weather event indicates an increase in the input of fresh fecal matter between the sampling stations in each water course. In particular, the increases in P.aeruginosa densities indicate input of fresh fecal matter, possibly from sewers, which is supported by the presence of CSO's.

3.3 Comparison of Dry and Wet Weather Results

The geometric mean densities for the dry weather surveys (Table 3.2) and the two wet weather events (Tables 3.6 and 3.7) at the stations H2, H3, B1 and B2 are shown as the histogram plots in Figures 3.3 (a) to (e) for each bacteriological parameter. These plots show that, in general, the densities for the wet weather events are much higher than those for the dry weather surveys.

For a quantitative comparison of the dry and wet weather results at the four stations H2, H3, B1 and B2, the ratios of wet weather event geometric means to those of the dry weather surveys for various bacterial parameters were computed. These ratios, summarized in Table 3.8, indicate that the wet weather geometric mean densities at the various stations were 3.4 to 377.1 times greater than the dry weather values for various bacteriological parameters. The Enterococcus group has the higher ratios (92.1 - 377.1). The average ratios of both events, shown in the table, are seen to range from 11.6 for FC to 207.0 for the Enterococcus group. This may be due to the possible increase of recent fecal pollution. It is also possible that the fairly high ratio is due to a decrease in time of travel between the source input and sampling locations because of higher flow rates during wet weather. This could have resulted in a better bacterial recovery on the media due to less environmental stress to the bacteria (M. Young, MOE Laboratory Services, Personal Communication).

The results presented in Table 3.8 also indicate that the ratios at various stations for the October event are higher than those for the November event with the exception of Enterococci at the Stations H2, H3 and B1, and

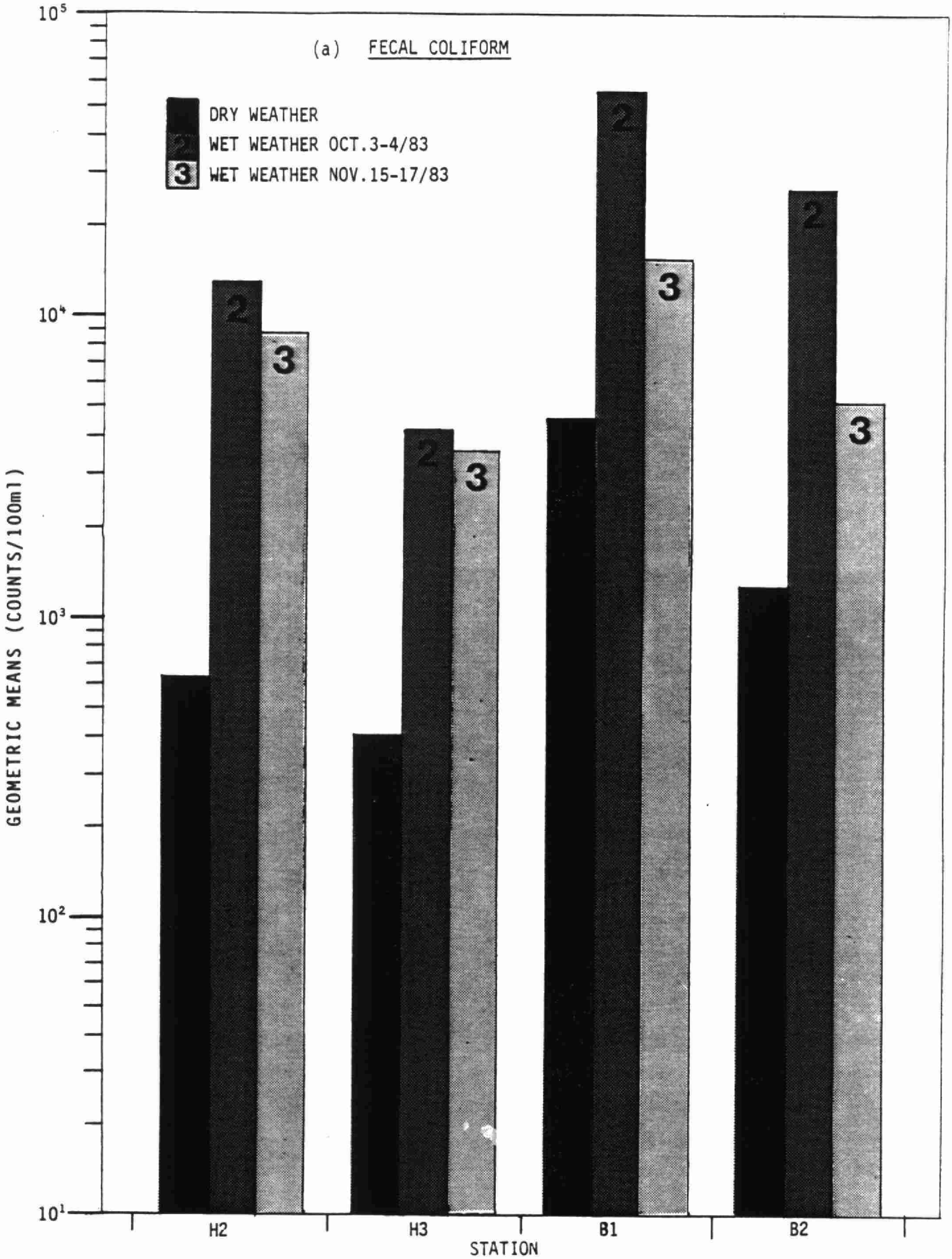


FIGURE 3.3 HISTOGRAM PLOTS OF DRY AND WET WEATHER BACTERIAL DENSITIES

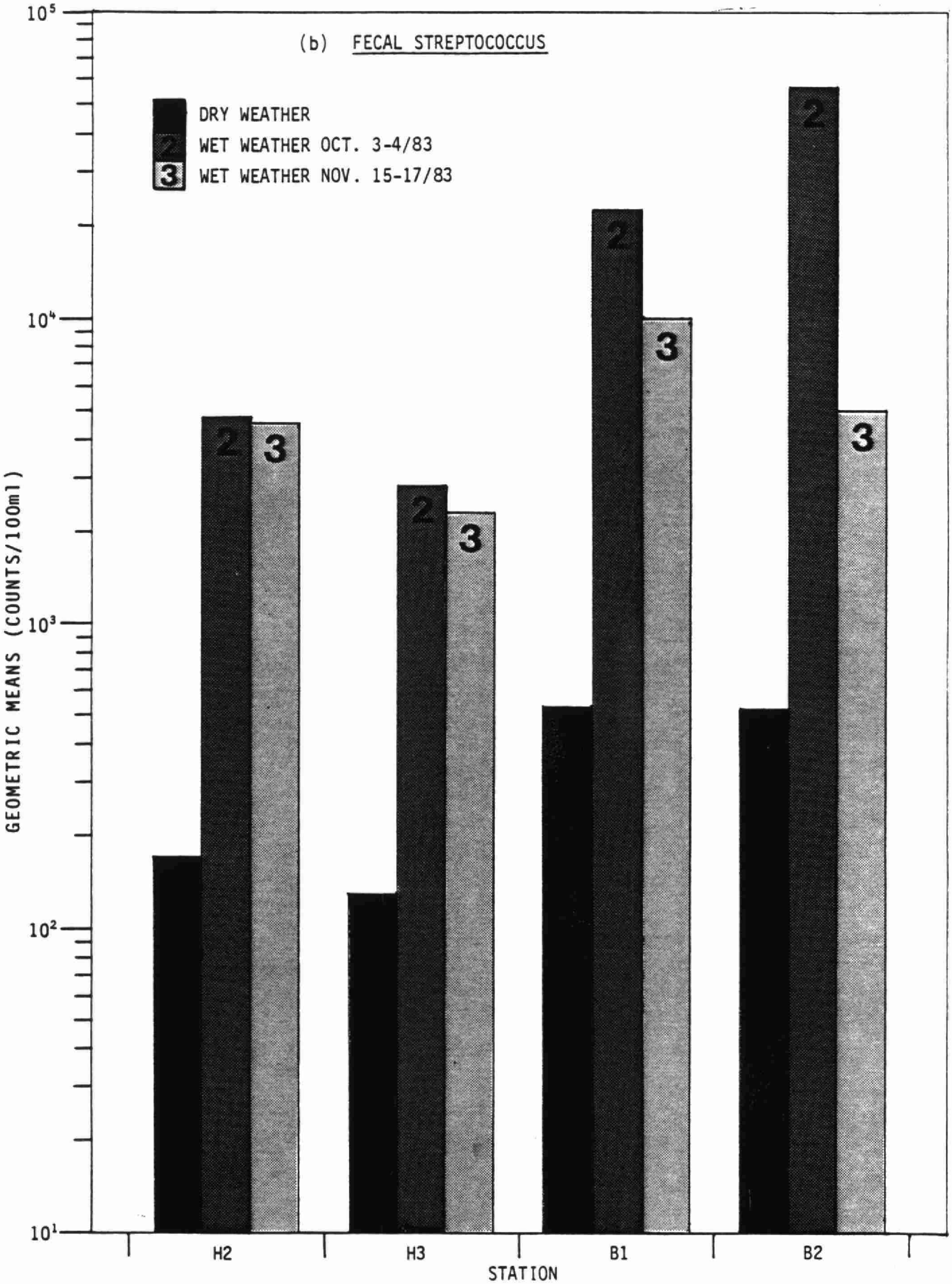


FIGURE 3.3 (Contd.)

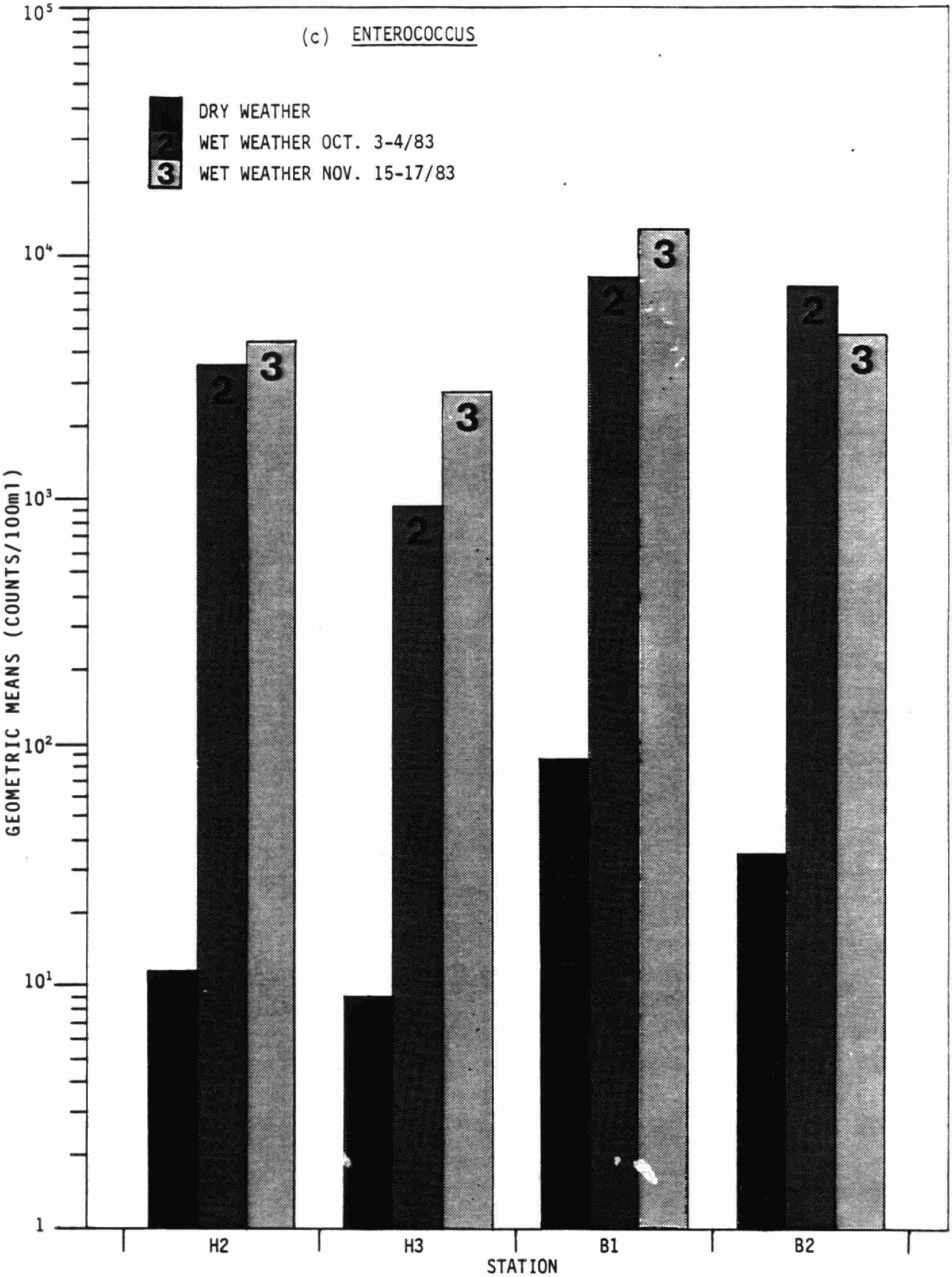


FIGURE 3.3 (Contd.)

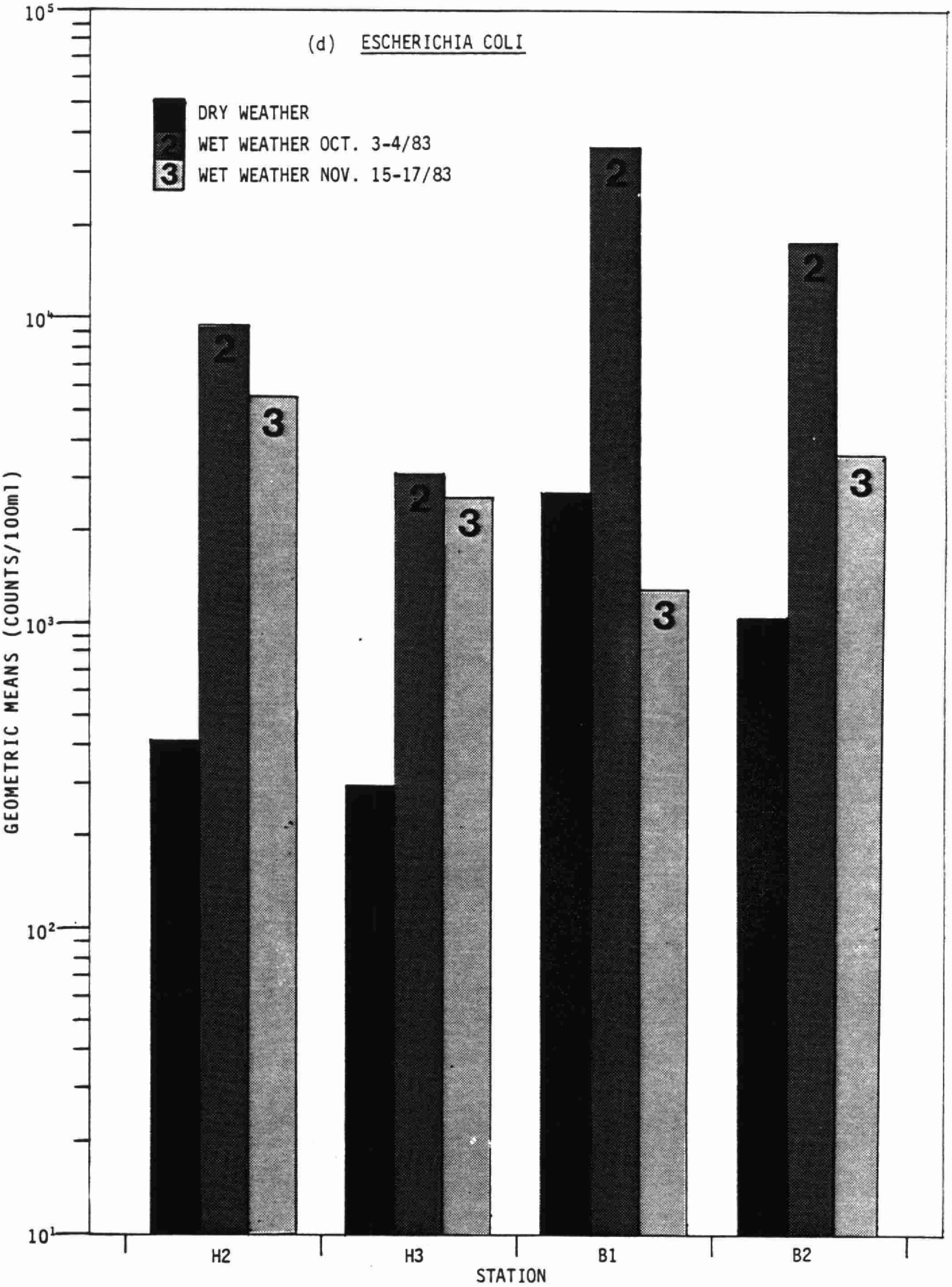


FIGURE 3.3 (Contd.)

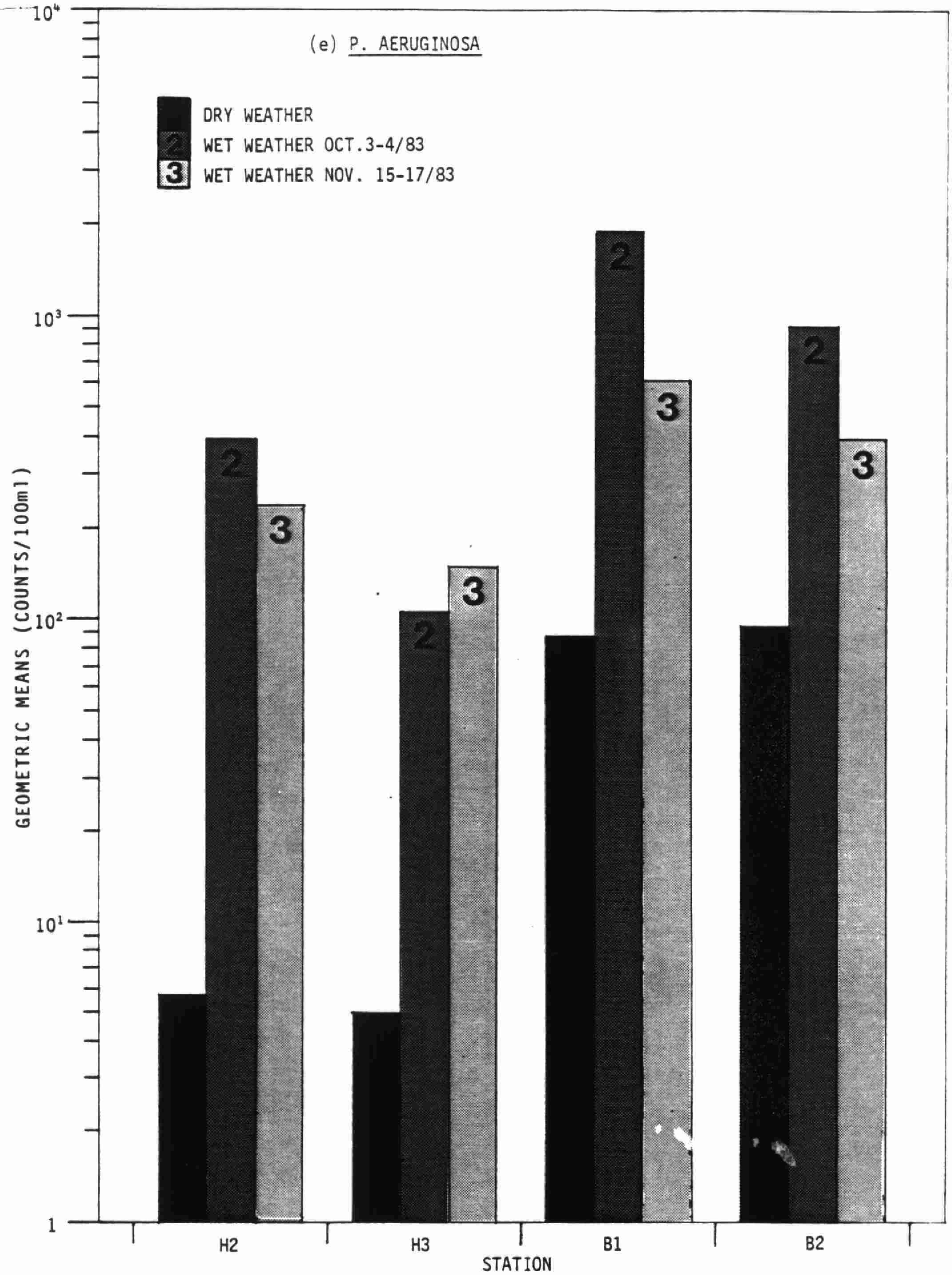


FIGURE 3.3 (Contd.)

TABLE 3.8

RATIOS OF WET WEATHER TO DRY WEATHER BACTERIAL DENSITIES

EVENT	STATION	RATIOS OF WET WEATHER TO DRY WEATHER GEOMETRIC MEAN VALUES				
		FC	FS	ENTERO-COCCUS	E.COLI	P.AERUGINOSA
October 3-4, 1983	H2	20.3	28.1	300.3	23.1	69.5
	H3	10.3	21.9	103.2	10.6	21.5
	B1	12.1	42.2	92.1	12.9	21.2
	B2	20.3	107.8	207.3	16.9	9.7
November 15-17, 1983	H2	13.9	27.3	377.1	13.3	40.9
	H3	8.8	17.8	299.9	8.9	29.9
	B1	3.4	18.5	145.3	4.7	7.0
	B2	4.0	9.3	130.5	3.4	4.1
Average Ratio		11.6	34.1	207.0	11.7	25.5

P.aeruginosa at Station H3. These appear to reflect the effects of the relative durations of the two events (being about 3 and 24 hours for the October and November events, respectively).

3.4 Assessment of Dry Weather Outfall Quality As a Source of Instream Contamination

For this assessment, the data from the dry weather outfall studies carried out in 1982 (Gartner Lee Associates Ltd., 1983) and the present dry weather surveys presented in Table 3.2, are utilized.

The 1982 dry weather outfall study data include FC and FS densities and discharges from various outfalls that were active during the dry weather periods. The outfalls were sampled from one to five times. These data were utilized by the MOE staff to compute geometric mean densities of FC and FS and arithmetic average of discharges from each outfall.

In the dry weather outfall study, the water courses were divided into a number of reaches and each active outfall within the reaches was identified by a number (Gartner Lee Associates Ltd., 1983). The designations of the reaches in the main Humber River and Black Creek for the bacteriological study area are shown in Figure 3.4. The average discharges and geometric mean densities of FC and FS for various outfalls have been summarized in Table C3, in Appendix C.

In order to assess the dry weather outfall quality as a course of instream bacterial contamination, a mass balance approach has been adopted. A brief description of the procedure and the results follow.

The bacterial die-off (or decay) in the streams can be described by the following first-order decay model:

$$c = c_o \exp(-Kt) \qquad (1)$$

in which c_o = bacterial density at the head of a segment (/100 mL)

c = bacterial density at the downstream end of the segment (/100 mL)

t = time of travel (hours)

K = die-off (or decay rate) of bacteria (hour^{-1})

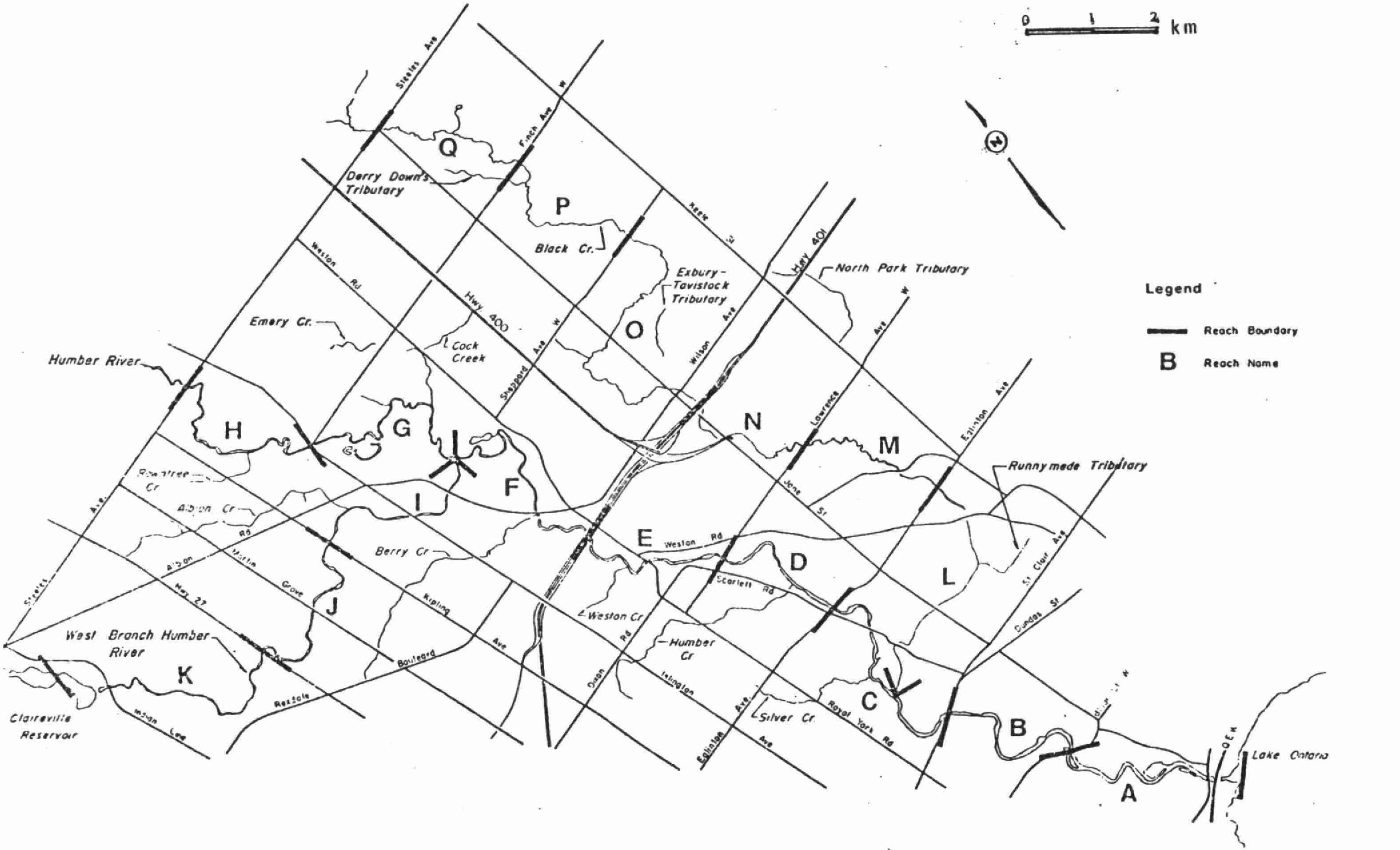


FIGURE 3.4 DRY WEATHER OUTFALL QUALITY STUDY - REACH DESIGNATION
(ADOPTRD FROM GARTNER LEE ASSOCIATES LTD., 1983)

In order to account for the inputs from various outfalls within the reaches shown in Figure 3.4, each reach was subdivided into a number of segments separated by node points, as shown schematically in Figure 3.5. The length of each segment ranges from 0.125 to 0.5 times the length of a reach. The node points between successive segments were serially numbered from 1 to 9 on Black Creek with eight segments, and from 1 to 27 in Humber River with 26 segments. A group of outfalls nearest to a node was considered as one point source entering the stream at that node. The outfall groupings at various nodes are shown on Figure 3.5. At any one node, the outfall and the instream background (i.e., just upstream from the outfall input) discharges were assumed to be completely mixed. The resulting discharge and bacterial density were computed from the following relationships:

$$Q_d = Q_u + \Sigma q_i \tag{2}$$

$$c_d = \frac{Q_u c_u + \Sigma (q_i c_i)}{Q_d} \tag{3}$$

where Q_u = background (upstream) discharge at a node (m^3/s)

Q_d = discharge just below the node (m^3/s)

q_i = discharge from each outfall, i, entering the stream at the node (m^3/s)

c_u = background bacterial density (/100 mL)

c_d = bacterial density just below the node (/100 mL)

c_i = bacterial density for the outfall, i, (/100 mL)

The time of travel was computed from

$$t = a \cdot Q^{-b} \tag{4}$$

where t = time of travel (hours)

Q = discharge (m^3/s)

and a & b = empirical constants

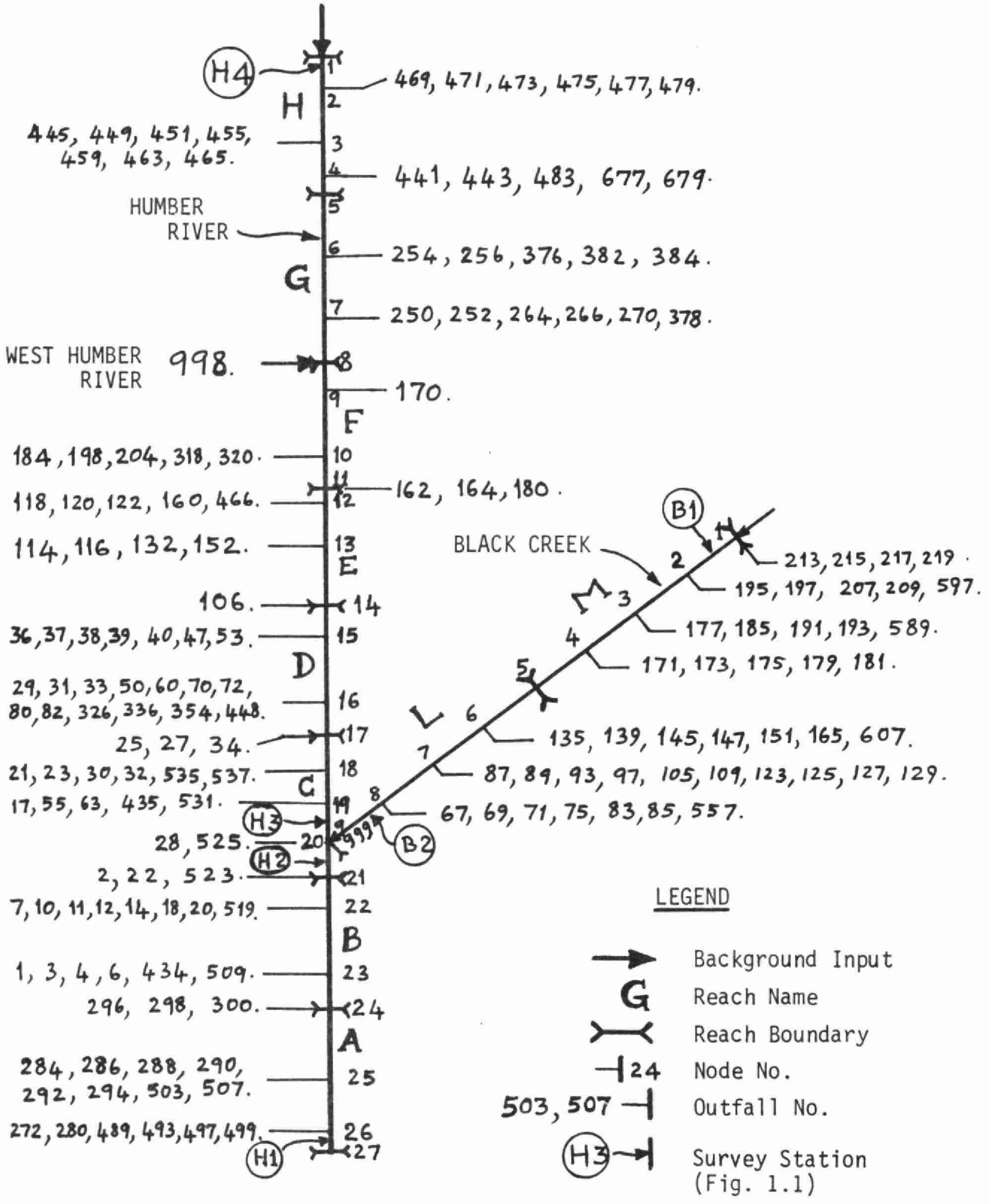


FIGURE 3.5 SCHEMATIC DIAGRAM SHOWING DRY WEATHER OUTFALLS DISCHARGING TO THE STREAMS

The values of a and b for various reaches (except reach A), provided by the MOE staff, are summarized in Table 3.9. Since there were no data for the reach A, it was assumed that the time of travel was one-half of that for the previous reach (based on proportional lengths of the two reaches). A computer model was utilized to perform the computations as per Equations 1 - 4.

The die-off (or decay) rates of FC and FS for the two water courses are not known. However, in order to gain some insight into the possible cause-and-effect relationships of bacterial transport in these water courses, the die-off values reported in the literature were considered. For fecal coliforms, instream decay rates (K_C) in the range 0.0004 - 0.146 per hour (20°C, base e) are reported (Zison, et al, 1978). Fecal streptococcus decay rates (K_S) for streams could not be found in the literature; however, for stormwater runoff, K_S values in the range 0.0019 - 0.0625 per hour have been reported (Zison, et al, 1978).

Instream bacterial densities at various nodes, predicted with selected values of the die-off rates (using the computer model), were compared with the observations available. If the predictions did not agree with the observations, new values of the die-off rates were selected and the model was re-run. The results obtained by this procedure for Black Creek and Humber River, are presented below.

<u>Black Creek</u>: The background conditions in Black Creek at Lawrence Avenue (Station B2) were the same as the average values from the September - October 1983 dry weather studies. The computed values for Black Creek at Scarlett Road (Station B1) with K_C = 0.07/hr and K_S = 0.07/hr are presented in Table 3.10, along with the observations for comparison. Table 3.11 shows a summary of the computational results for various nodes in Black Creek. The computed discharge and the FC density are in reasonable agreement with the observed mean values at Station B1 (see Table 3.10). However, the computed FS density is about 2.7 times higher than the observed mean density. The value, K_C = 0.07/hr, is within the range in the literature, whereas K_S = 0.07/hr is slightly higher than the reported maximum. (Note: with K_S = 0.20/hr, the computed FS density at Station B2 was 1100.5/100 mL). These results indicate that in Black Creek, the dry weather outfall quality is a main source of instream contamination with respect to fecal coliforms. However, the fecal streptococci results show a faster disappearance in Black Creek during

TABLE 3.9

DATA FOR TIME OF TRAVEL COMPUTATION

STREAM	LOCATION	REACH	a	b
Black Creek	Lawrence Ave. to Humber River Confluence	N & M	3.0644	0.5534
Humber River	Steeles Ave. to West Humber River Confluence	H & G	8.833	0.3970
Humber River	West Humber River to Lawrence Ave.	F & E	11.708	0.5550
Humber River	Lawrence Ave. to Scarlett Rd.	D & C/4	4.845	0.6230
Humber River	Scarlett Rd. to Bloor St.	3C/4 &B	9.612	0.5118
Humber River	Bloor St. to Lakeshore Blvd.	A	4.806*	0.5118

* One-half of the value in the previous reach.

TABLE 3.10

OBSERVED AND COMPUTED DRY WEATHER BACTERIAL DENSITIES

Station	Observed Mean Values *			Computed Values		
	Discharge m^3/s	FC /100 mL	FS /100 mL	Discharge m^3/s	FC /100 mL	FS /100 mL
Black Creek @ Scarlett Station B1	0.1954	4548.2	537.7	0.1648	4659.5	1458.8
Humber River @ James Gardens Station H3	--	403.9	130.0	2.1220	200.4	125.5
Humber River @ Dundas Street Station H2	--	627.3	172.3	2.3349	569.5	164.1
Humber River @ Lakeshore Blvd. Station H1	--	617.2	80.0	2.3971	615.6	189.2

* September - October 1983 Dry Weather Study Data

TABLE 3.11
SUMMARY OF MASS BALANCE COMPUTATIONS

(A) BLACK CREEK - LAWRENCE AVENUE TO HUMBER RIVER CONFLUENCE

NODE	SUMTOT	TOT	FLOW	FC	FS
1	0.00	0.00	0.0900	1245.3	531.5
2	1.41	1.41	0.0943	1098.6	505.3
3	2.77	1.36	0.1013	1522.8	701.1
4	4.04	1.26	0.1160	1700.9	685.7
5	5.25	1.22	0.1236	1561.9	629.7
6	6.47	1.22	0.1236	1743.4	614.8
7	7.64	1.17	0.1340	2791.5	1516.3
8	8.69	1.05	0.1621	4659.5	1458.8
9	9.73	1.04	0.1648	4332.7	1356.5

(B) HUMBER RIVER - STEELES AVE. TO LAKESHORE BLVD.

NODE	SUMTOT	TOT	FLOW	FC	FS
1	0.00	0.00	1.6210	127.0	88.0
2	0.91	0.91	1.6210	128.3	88.5
3	2.27	1.36	1.6377	135.1	89.4
4	3.18	0.91	1.6439	134.9	91.1
5	3.63	0.45	1.6499	134.9	91.1
6	4.99	1.36	1.6499	135.6	91.5
7	6.35	1.36	1.6512	146.6	108.8
8	7.25	0.90	1.6641	138.7	96.5
9	8.23	0.98	2.0641	138.6	96.7
10	10.18	1.96	2.0661	138.6	96.6
11	11.16	0.98	2.0712	139.1	98.2
12	11.65	0.49	2.0726	139.4	99.9
13	13.11	1.46	2.0773	140.2	100.8
14	15.06	1.95	2.0805	153.0	101.2
15	15.68	0.61	2.0810	160.8	102.2
16	16.90	1.23	2.0843	168.9	122.6
17	17.51	0.61	2.1052	168.8	122.6
18	18.12	0.61	2.1066	200.8	125.1
19	19.06	0.94	2.1220	200.4	125.5
20	19.99	0.93	2.1369	564.2	160.1
21	20.88	0.89	2.3349	569.5	164.1
22	21.77	0.89	2.3526	602.4	176.7
23	23.54	1.77	2.3594	616.2	184.2
24	24.41	0.88	2.3725	616.8	184.7
25	25.96	1.54	2.3741	616.5	187.2
26	27.11	1.15	2.3882	615.6	189.2
27	27.50	0.38	2.3971	615.6	189.2

SUMTOT: CUMULATIVE TRAVEL TIME (HOURS)
TOT: TRAVEL TIME FROM NODE i TO NODE i+1 (HOURS)
FLOW: DISCHARGE (m^3/s)
FC: FECAL COLIFORM DENSITY (/100 mL)
FS: FECAL STREPTOCOCCUS DENSITY (/100 mL)

September - October 1983 dry weather studies when compared to the computed values; this discrepancy cannot be explained based on available information.

Humber River: The background conditions in the Humber River at Steeles Avenue (Station H4) were also taken to be the same as the averages from the September October 1983 dry weather studies. The inputs from the West Humber River, shown as 998 in the outfall grouping at the node No.8 on Figure 3.5, were: discharge = 0.4 m^3/s; FC = 106/100 mL; and FS = 45/100 mL (based on the data provided by MOE staff).

The Black Creek inflow quality parameters, shown as 999 at the node No.20 on Figure 3.5, were also the same as those for the September - October 1983 dry weather studies. The computed values of FC and FS with various values of K_C and K_S in the range stated earlier were generally much lower than the observations; therefore, the computations were performed with $K_C = 0$ and $K_S = 0$. Table 3.10 shows the observed mean and computed values for the three stations H1 - H3 in the Humber River. The detailed computational results for various nodes, including the travel times, discharges and the bacterial densities, have been summarized in Table 3.11.

A comparison of the observed and computed discharge values at the three stations H1, H2 and H3 is not possible since there are no observations. However, the computed discharge of 2.0805 m^3/s at node No.14 is in reasonable agreement with the value of 2.065 m^3/s observed at the Water Survey of Canada Gauging station in the Humber River at Lawrence Avenue (nearest to the node). The computed FC densities at the three stations are close to 50%, 91% and 100% of the corresponding observed densities. The FS densities for the three stations, in order, are 96%, 95% and 236% of the observed values. These results indicate: (a) close agreement between the observed and computed values of FC at Stations H1 and H2, and of FS at Stations H2 and H3; and (b) a possibility of the presence of additional FC sources in the Humber River above James Gardens. The observed FS densities at Station H1 may be a result of higher dilution caused by the lake currents; since this is not the case with FC, the reasons for the discrepancies are unknown.

The simple computational procedure adopted here is subject to several assumptions as stated earlier, and hence, the computational results should be interpreted in light of these assumptions and their possible limitations. The bacterial densities in streams and rivers are known to be affected by various

factors and processes such as sedimentation, resuspension, growth and die-off, light intensity, etc. (Mitchell, 1978; Zison et al, 1978; Mancini, 1978). Also, the observed densities may be affected by bacterial inputs from waterfowl and other unknown sources. The computations do not consider these factors and processes. It should be noted that the computations for the Humber River are based on zero decay rates of FC and FS bacteria. In light of these limitations, it is felt that the results presented in Table 3.10 tend to indicate that the dry weather outfall loading is one of the main sources of bacterial contamination of the stream waters in dry weather, and that there exists a possibility of the presence of additional FC bacterial sources in the Humber River above James Gardens (Station H3).

3.5 Identification of Bacteriological Quality and Problem Areas

The data collected in the fall 1982 (October - November) and summer 1983 (July) TAWMS surveys, and in the present study (September - November 1983) have been utilized in this component of the study.

The TAWMS fall 1982 studies consist of two dry and three wet weather surveys at five Humber River stations and two Black Creek stations. In the July 1983 TAWMS Study, sampling was carried out on one occasion only at the same stations as 1982, in the two water courses. In the fall 1982 surveys, FC and FS were monitored whereas in the 1983 survey, FC and P.aeruginosa were determined. The fall 1982 survey data were utilized to determine the geometric mean densities of FC and FS and FC/FS ratios for the dry weather, wet weather, and combined dry and wet weather conditions. The results of the TAWMS 1982 and 1983 studies are presented in Table C2 in Appendix C.

Altogether, the TAWMS 1982 and 1983, and the September - November 1983 studies provide data at ten stations, eight on Humber River and two on Black Creek. The locations of these ten stations are shown on the map in Figure 3.6. For convenience, these stations are serially numbered from 51 to 60, as shown on the figure.

Histogram plots of FC densities at various stations are shown on Figures 3.6 (a) and (b) for the dry and wet weather conditions, respectively. These plots show that the FC objective of 100/100 mL is in noncompliance at all stations under both the dry and wet weather conditions, the only exceptions being

51 - Humber River @ Steeles
52 - Humber River @ West Humber
53 - Humber River @ Lawrence Ave.
54 - Humber River @ Scarlett
55 - Humber River @ James

56 - Humber River @ Dundas West
57 - Humber River @ Bloor
58 - Humber River @ Queensway
59 - Black Creek @ Lawrence Ave.
60 - Black Creek @ Scarlett

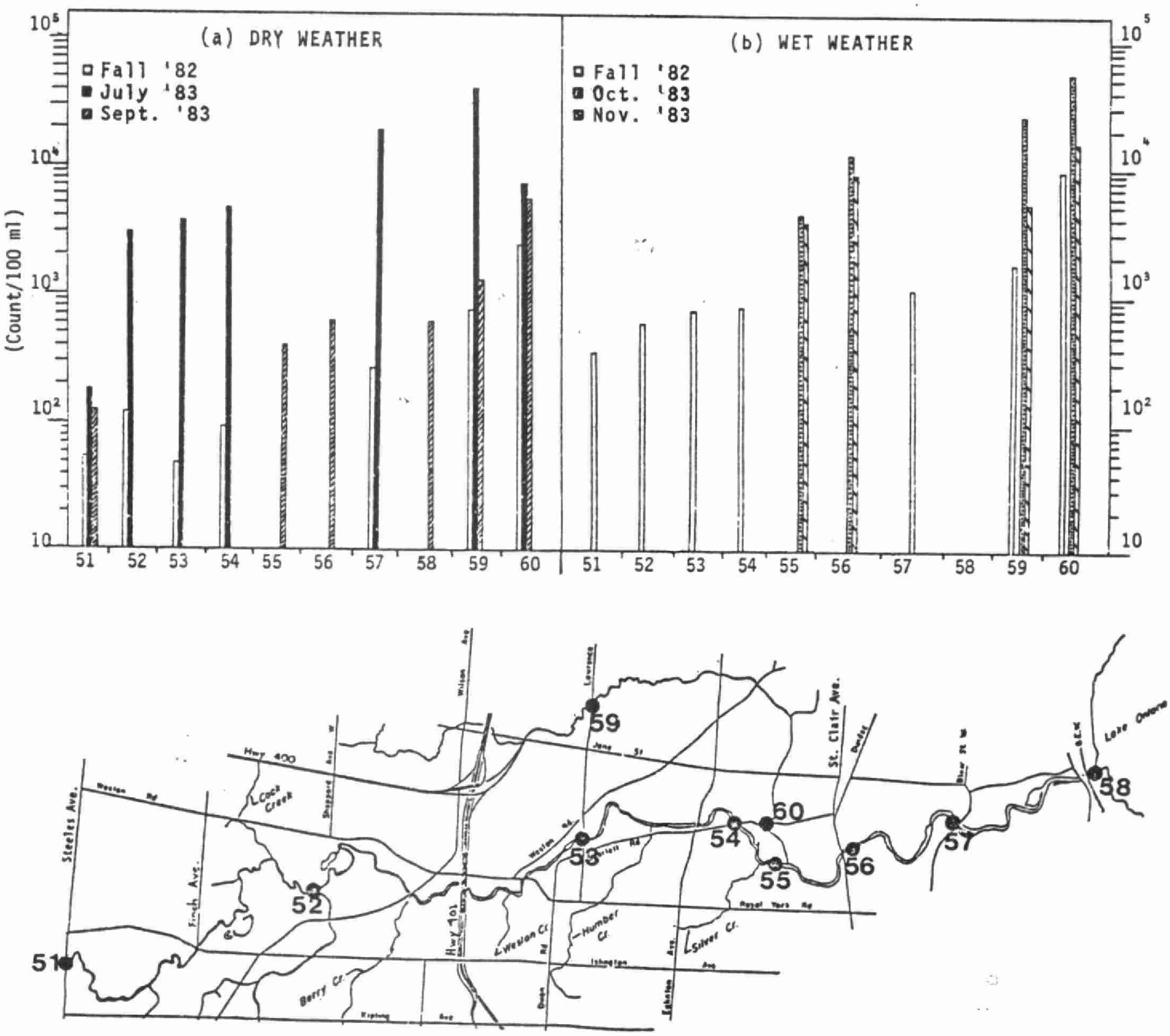


FIGURE 3.6 - FECAL COLIFORM DENSITIES WITHIN THE STUDY AREA

Humber River at Steeles, Lawrence and Scarlett (Stations 51, 53 and 54) during the fall 1982 dry weather studies. The densities are observed to be the highest at the two Black Creek stations. These results indicate that the bacteriological quality within the study area is generally in noncompliance with the recreational water quality objectives, and that Black Creek is, in particular, a highly contaminated area.

Figure 3.7 shows FC/FS ratios at various stations. The ratios range from less than 1 to over 10, thus indicating possible fecal contamination from a mixture of human and animal waste sources. However, Stations 58 and 60 seem to be affected by a mixture of human and Group I, and possibly Group II waste sources located upstream, as indicated by the relatively higher FC/FS ratios.

In summary, the bacteriological quality within the two water courses in the study areas is generally in noncompliance with the FC objective of 100/100 mL, although in some instances the objective is met. Thus, overall, the entire study area appears to be a "problem area" with respect to bacteriological quality, Black Creek being the most highly polluted area.

3.6 Origin of Fecal Contamination of Stream Waters in the Study Area

Attempts have been made to identify the origin of fecal contamination of stream waters in the study area through an evaluation of the data gathered during the present study and the TAWMS 1982 and 1983 surveys. Information on the combined sewer overflow locations, supplied by the MOE project staff, is also utilized in this evaluation. The relative values of FC/FS ratio data, calculated from the geometric mean bacterial densities, form the basis for this evaluation. The detailed bacteriological studies for identification of the bacterial species in the September - November 1983 study water samples, being carried out by the MOE Microbiology Laboratory, are likely to define the origin of contamination of stream waters more precisely than the present approach. The results of the MOE studies are likely to be available during the summer, 1985. Also, microbiological studies on species being carried out at the University of Toronto should provide additional information.

The FC/FS ratios for the September - October 1983 dry weather surveys, presented in Table 3.2 and in Figure 3.7, indicate relatively high values at two locations: Humber River at Lakeshore (Station H1) and Black Creek at

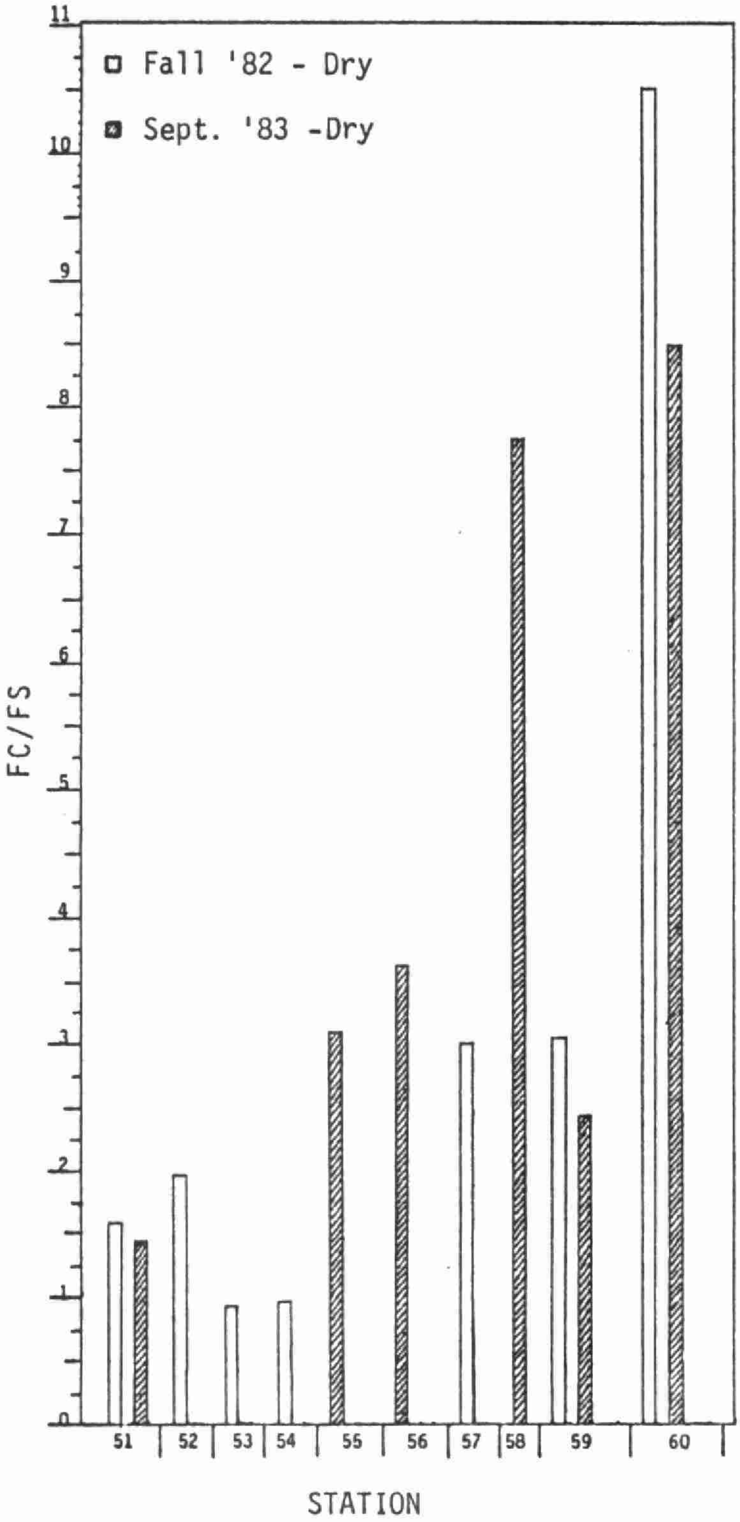


Figure 3.7

FC/FS RATIOS AT VARIOUS STATIONS
IN THE HUMBER RIVER BASIN

Scarlett Road (Station B1). The TAWMS fall 1982 dry weather study data indicate somewhat similar FC/FS ratios in Black Creek at Scarlett Road (Station B1); however, Station H1 was not monitored in the TAWMS study. These results suggest the possibility of fecal contamination by human and Group I origin waste sources (i.e., gull, duck, dog and human feces) near Stations H1 and B1. (Note: there are no data on FS for the July 1983 survey, and hence the FC/FS ratios could not be determined).

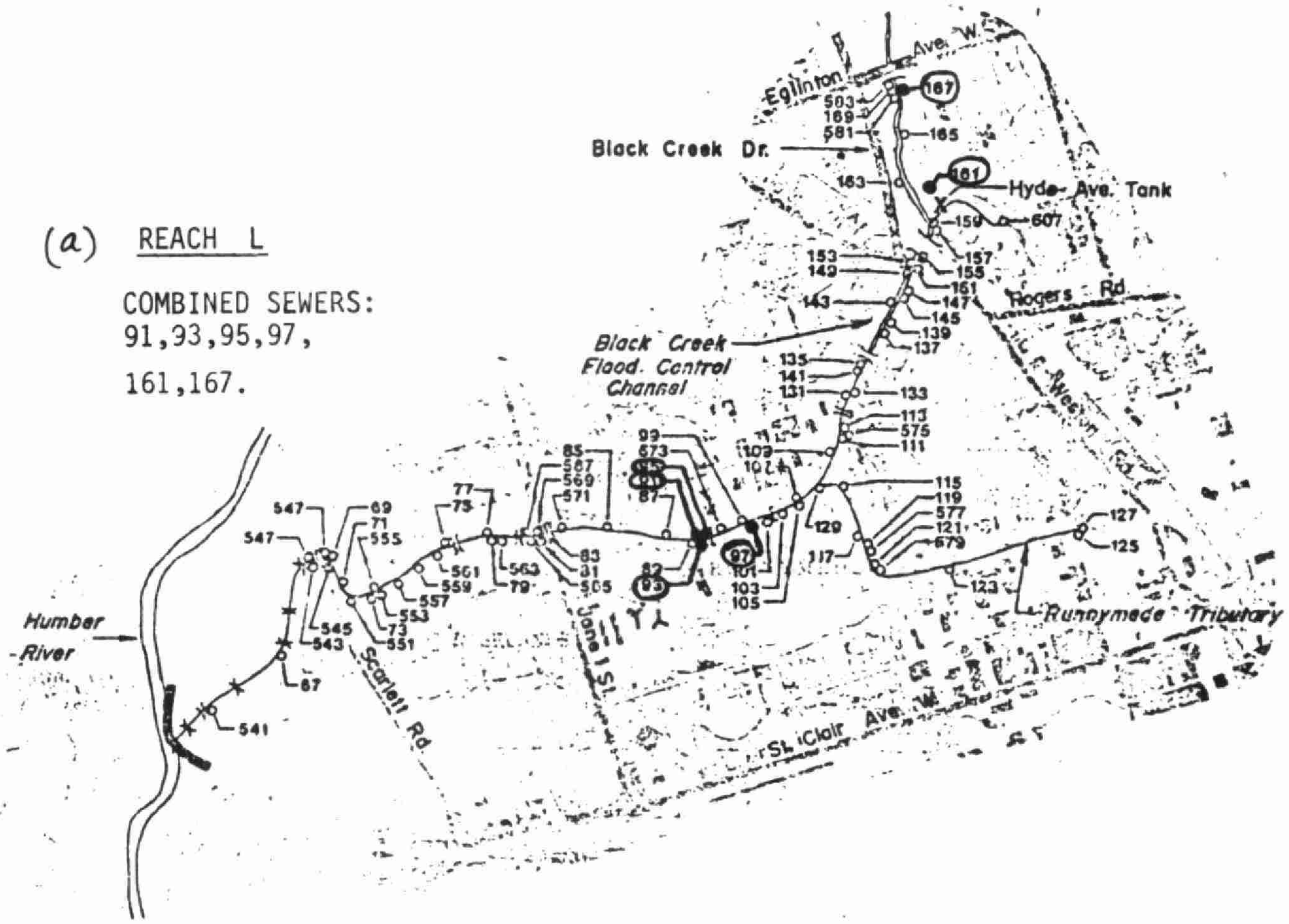
The technical report from the dry weather outfall study (Gartner Lee Associates Ltd., 1983) shows the list of active outfalls in various reaches of the two water courses. Seven of these are known to be combined sewer overflows (CSO), according to the information supplied by the MOE staff. There are six CSO's identified on Black Creek upstream from Station B1 and one on the Humber River above Station H1; these are shown on Figures 3.8 (a) and (b). However, the inputs from two of these CSO's, namely #95 and #167, are known to be small relative to the others. It appears that these combined sewers as well as the numerous contaminated sewers (refer to Appendix C) are one of the major sources of fecal contamination of stream waters. It is possible that a major fecal source is of human and Group I origin, causing the relatively high FC/FS ratios in Black Creek at Scarlett Road (Station B1) and Humber River at Lakeshore Blvd. (Station H1).

At all the other stations within the study area, the 1982 and 1983 dry weather study data reveal FC/FS ratios in the range 0.89 - 3.17, suggesting fecal pollution of the stream waters due to Group II waste sources located very close to the sampling stations, human and Group I sources situated at farther distances from the Stations or a combination of both. During the September - October 1983 dry weather studies, birds and other water fowl were found to be present at some locations (see Tables A1 A6 in Appendix A); however, no attempt was made to estimate the possible degree of fecal pollution from the waterfowl.

The wet weather survey results of TAWMS fall 1982, and October - November 1983 studies show that the FC/FS ratios never exceed 4 at any station (based on the geometric mean densities). The TAWMS fall 1982 results reveal that the ratios were lower than 1.0 at all stations except Black Creek at Scarlett Road and Humber River at Bloor Street where the ratios were in the range 1.0 - 4.0. These results suggest fecal pollution of stream waters due to the Group II (non-human) waste sources at the latter two stations and Group III (non-human)

(a) REACH L

COMBINED SEWERS:
91,93,95,97,
161,167.



(b) REACH A

COMBINED SEWER:
288

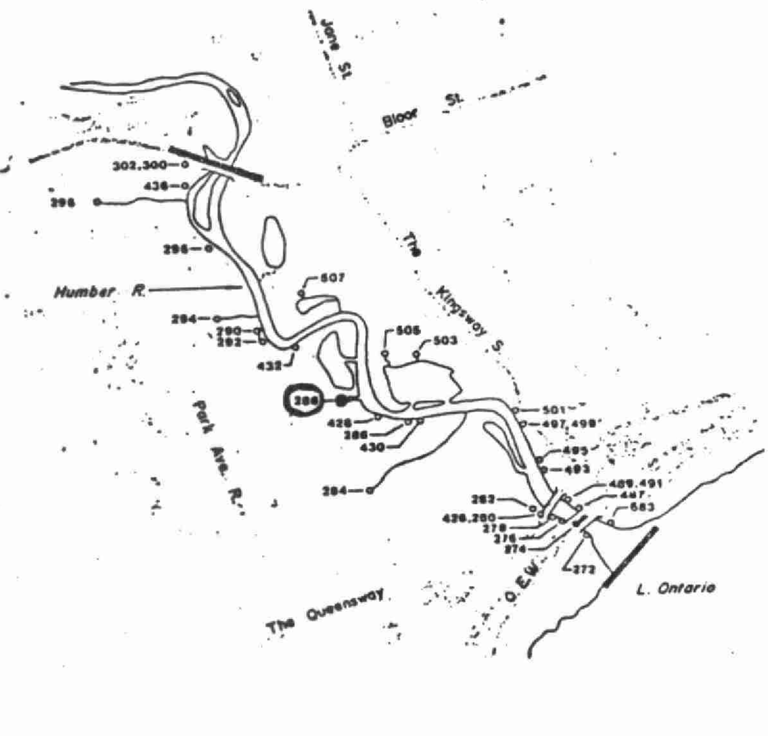


FIGURE 3.8 COMBINED SEWER OVERFLOW LOCATIONS

waste sources at all the other locations or human and Group I fecal source contributions from upstream locations. The October - November 1983 studies shows that the ratios lie in the range 1.0 4.0 at the three stations, B1, H2 and H3, but are less than 1.0 at Station B2, thus indicating possible fecal pollution due to Group II waste sources at the former three stations and mainly due to Group III waste sources at the latter location. However, the ratios could also be due to greater distances between Group I and Group II sources and sampling stations. The ratios within each wet weather event show systematic variation with time at some locations, but fluctuate at some other locations. These changes in the ratios appear to be due to combined sewer overflows and other contaminated sewer discharges, as well as wash-off of non-human origin wastes during the events. On an overall basis, the wet weather results indicate possible fecal contamination of stream waters due to both human and non-human waste sources.

Based on the above analyses, the suspected origins of fecal contamination of stream waters within the study area can be summarized as follows:

Black Creek at Scarlett Road	-	Human, Group I and Group II waste sources, the former being due to combined and other contaminated sewer discharges during dry weather or due to sources located farther upstream or a combination of both.
Humber River at Lakeshore Blvd.	-	Same as above.
All other locations	-	Group III sources located close to the stations or within study area mixture of Human and Groups I - III sources located farther upstream.

3.7 Bacteriological Trends

In order to identify trends in bacteriological water quality within the study area, the historical water quality data for the period 1977 to 1981 have been utilized from the following stations:

Humber River at Bolton WPCP
Humber River at Lakeshore Boulevard
Black Creek at Scarlett Road

The historical water quality data (Table C1 in Appendix C) were utilized in conjunction with rainfall data records to identify the observations which were likely to be affected by wet weather events. A water quality observation was considered to be affected by wet weather when the total rainfall for the sampling day plus two previous days exceeded an arbitrary value of 3 mm. Based on a review of the rainfall data at various meteorological stations in the basin, the average rainfall at the Keele-Finch and Old Weston Stations was considered to be representative for this analysis. This procedure resulted in identification of "dry" and "wet" weather observations at each of the above-mentioned three stations. The TAWMS fall 1982 survey data for Black Creek at Scarlett Road, consisting of two dry and three wet weather events, are also utilized for the trend analysis.

The geometric mean bacteriological densities of FC and FS at each station were determined for the dry and wet weather conditions, as well as for the combined case. These results were utilized to plot FC and FS densities versus time, presented in Figures 3.9, 3.10 and 3.11 for the dry, wet and combined cases, respectively. Plots of (FC/FS) ratios versus time for dry weather are shown in Figure 3.9.

The plots show a general decline of FC and the ratio (FC/FS) with time in the Humber River at Bolton. Specifically, the FC values ranged from 1,000 to 10,000/100 mL in 1977 - 1978 and from 100 to 1,000/100 mL from 1979 on. For the FC/FS ratio in Humber River at Bolton during dry weather, a similar trend is evidenced with the ratio dropping in 1977 - 1978 from the 5 to 15 range down to about the 0 to 2 range. For FS, no dramatic trend was observed although a slight downward trend is seen in the plots for the dry and wet weather data.

In spite of the downward trend in FC observed, the values were in excess of the Provincial Water Quality Objective (PWQO) of 100/100 mL for the wet events of 1979 and 1981 and the dry events of 1980 (see Figure 3.10). An examination of the combined FC levels in Figure 3.11 shows that the levels were higher than 100/100 mL for the years 1979 through 1981. This indicates that, although there has been a significant reduction in FC levels in Humber River at Bolton, the PWQO is still being exceeded at this station.

For the Black Creek at Scarlett Road Station and the Humber River at Lakeshore Blvd. Station, the plots shown in Figures 3.9 and 3.10 indicate that the PWQO

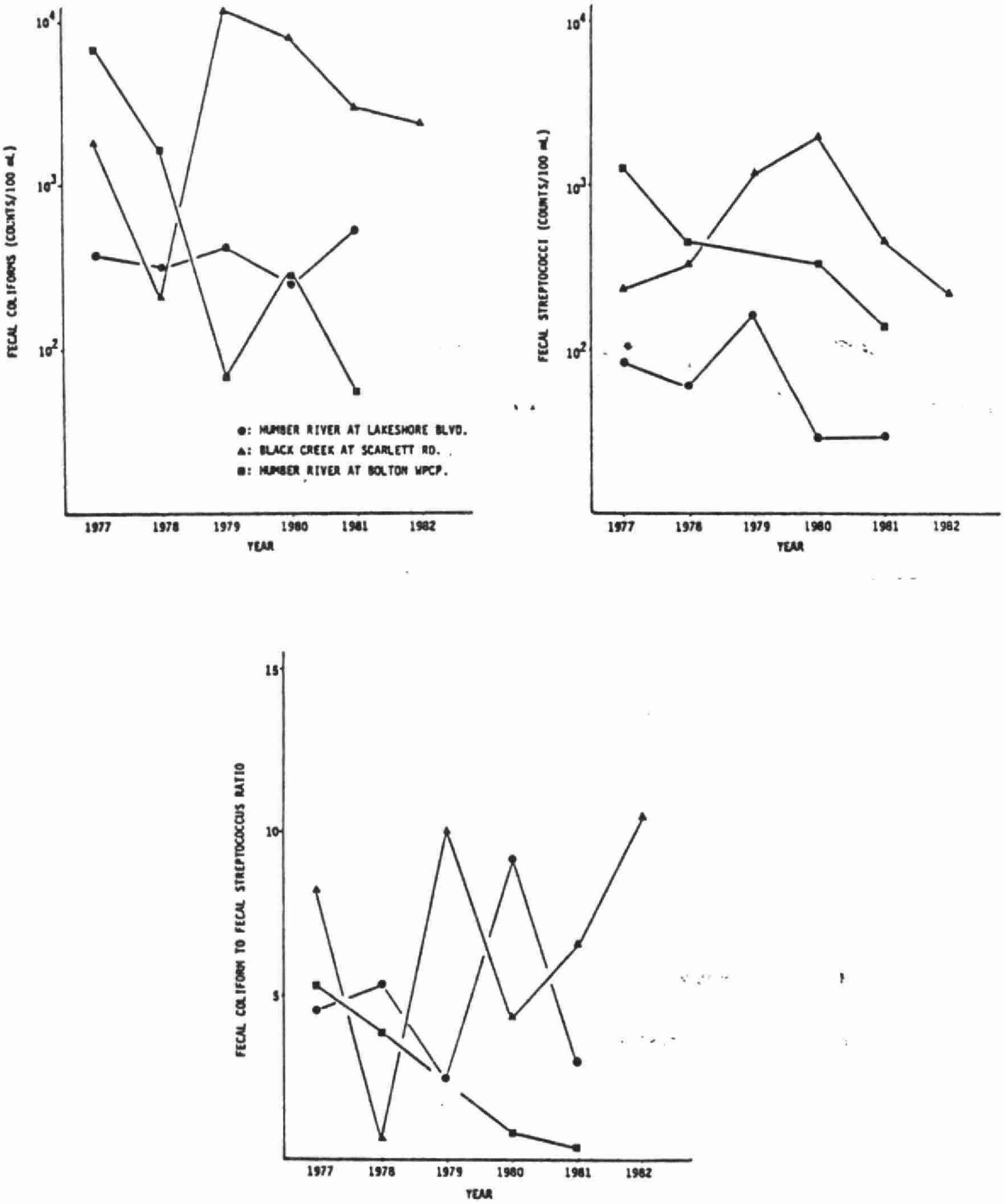


FIGURE 3.9 BACTERIAL TRENDS - DRY WEATHER

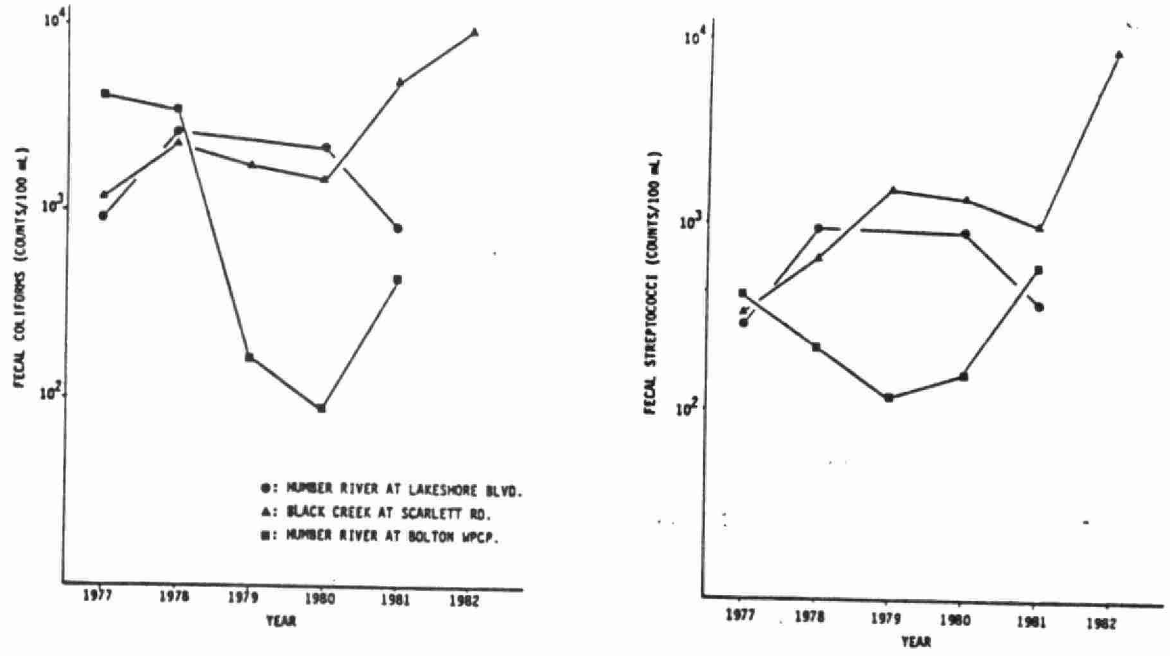


FIGURE 3.10 BACTERIAL TRENDS - WET WEATHER

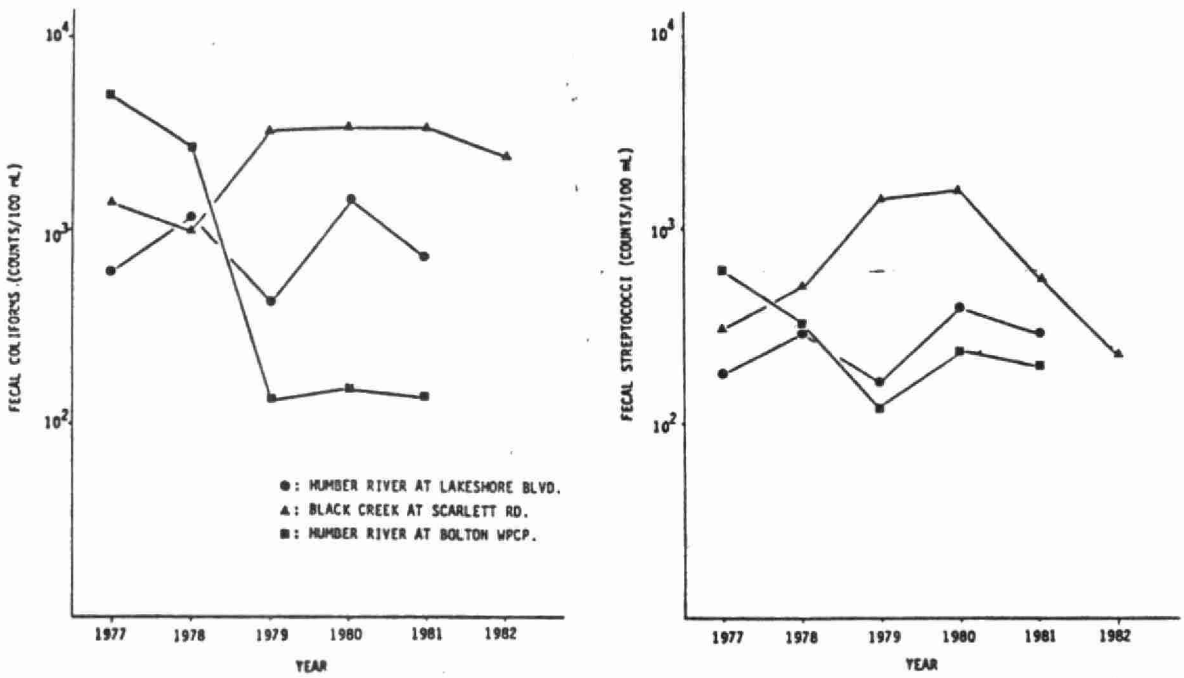


FIGURE 3.11 BACTERIAL TRENDS - COMBINED DRY AND WET WEATHER

for FC was exceeded during both dry and wet periods in each of the years for which data was available. The plot for the combined dry and wet events (Figure 3.11) shows no significant trend although there is a plateau of higher FC levels for the Black Creek at Scarlett Road Station from 1979 through 1982. The plots for dry weather events only and for wet weather events only show somewhat higher geometric mean FC levels for this station from 1979 through 1982.

The ratios FC/FS in Black Creek at Scarlett Road show a fluctuation for dry weather increasing from about 5 in 1980 to over 10 in 1982. These results could indicate the possibility of an increase in human and Group I waste sources since 1980 in the vicinity of Black Creek above Scarlett Road.

4 CONCLUSIONS AND RECOMMENDATIONS

Studies were carried out in Humber River and Black Creek to establish bacteriological quality relative to recreational water quality objectives and to identify the origins of fecal contamination in the Humber River. The studies included ten dry and two wet weather surveys. The bacteriological parameters monitored include fecal coliform (FC), fecal streptococcus (FS), enterococcus, E.coli and P.aeruginosa. The recreational water quality objectives for these parameters were as per the MOE provincial water quality objectives (PWQO) and the IJC draft recommendations (see Table 1.4).

The ten dry weather surveys (including one on a Sunday) were carried out during September 12 October 25, 1983, and the wet weather events were monitored during October 3 - 4, 1983 and November 15 - 17, 1983. Historical data for the period 1977 - 1981 and the TAWMS fall 1982 and July 1983 studies data were also utilized in evaluating the origin of fecal contamination of stream waters, identification of bacterial quality and problem areas and bacterial trend analyses. Summaries of meteorological and streamflow data for selected stations are presented.

The following conclusions are derived from the results of this study:

1. The dry weather studies of September - October 1983 indicate that:

   - The geometric mean FC densities are in noncompliance with the PWQO of 100/100 mL at all stations.

   - Generally, the densities of FC and FS in Humber River increase from upstream to downstream stations except for a slight decline at Lakeshore Blvd.

   - The FC densities increase in Black Creek from Lawrence Avenue to Scarlett Road by about 3.5 times, while FS densities remained almost unchanged.

   - The densities of various bacterial parameters were at least five times greater in Black Creek than in Humber River.

- The FC/FS ratios were 7.71 and 8.46 in the Humber River at Lakeshore and Black Creek at Scarlett Road, respectively, and ranged from 1.43 to 3.64 at all other stations.

- The Enterococci densities were in noncompliance with the IJC recommended objective of 11/100 mL in Humber River at Dundas and Lakeshore, and in Black Creek at Lawrence and Scarlett; and the densities generally increased from upstream to downstream stations.

- The densities of E.coli exceed the IJC recommended objective of 23/100 mL at all six stations, showing an increasing trend from upstream to downstream locations.

- P.aeruginosa densities increase from upstream to downstream stations in the Humber River, but decline slightly in Black Creek; the IJC recommended objective (see Table 1.4) was met in the Humber River at James Gardens and Lakeshore, but not at other locations.

- The bacterial quality in Black Creek at Scarlett Road was in noncompliance (in all 10 observations) with the PWQO for FC and the IJC recommended objectives for Enterococci, E.coli and P.aeruginosa.

2. The results of the two wet weather events are as follows:

   - The densities of each bacterial parameter were at least five times higher in Black Creek than in Humber River.

   - Generally, the densities increased from upstream to downstream stations except for a decline in FS in Black Creek during the October event.

   - The FC/FS ratios showed an increasing trend with time in the October event and a decreasing trend in the November event.

3. A comparison of the dry and wet weather results shows that the wet weather bacterial densities are 3.4 to 377.1 times higher than the dry weather densities, being the highest for the Enterococcus group.

4. An evaluation of the dry weather outfall quality as a source of instream contamination using a mass balance approach with first-order decay (die-off) of bacteria indicates that:

   - The computed FC densities in Black Creek and in the Humber River at Dundas Street and Lakeshore Blvd. are very close to the corresponding observations under dry weather conditions.

   - The computed FS densities are higher than the observed values in Black Creek and very close to the observations in the Humber River at James Gardens and Dundas Street.

   - On an overall basis, considering the assumptions and possible limitations, there is reasonable justification to conclude that the dry weather outfall bacterial loading is one of the main sources of the instream fecal contamination during dry weather. There is a possibility of the existence of additional bacterial sources in the Humber River above James Gardens (i.e., Station H3).

5. An assessment of the bacteriological quality at eight stations in the Humber River and two stations in the Black Creek based on the data gathered during the TAWMS fall 1982 and July 1983 and the present studies, reveals that:

   - The PWQO of 100/100 mL for FC is not complied with, except for three stations Humber River (at Steeles, Lawrence and Scarlett) during the fall 1982 dry weather studies.

   - The FC densities are the highest in Black Creek.

   - The bacteriological quality in the entire study area of the two water courses is generally unsuitable for body contact recreation, Black Creek being the most highly polluted area.

6. Attempts made to identify the possible sources of fecal pollution utilizing relative values of FC/FS ratios from the TAWMS fall 1982 and July 1983 and the present studies data, as well as information on combined

sewer overflow locations (six in Black Creek upstream from Scarlett Road and one in Humber River above Lakeshore Blvd.) show that:

- There is an increased likelihood of human-origin waste sources causing fecal contamination in the Black Creek above Scarlett Road and Humber River above Lakeshore Blvd. Combined sewer overflow sites have been identified in these locations. A mixture of human and non-human animal wastes is possibly the predominant source of fecal contamination of stream waters at all other locations in the two water courses.

7. Analyses of historical water quality data from three stations (Humber at Bolton and Lakeshore, and Black Creek at Scarlett Road) for the period 1977 - 1981 and the TAWMS fall 1982 data to identify bacteriological trends in dry and wet weather events reveal that:

   - The FC levels declined, FS densities did not change and FC/FS ratios declined in Humber River at Bolton.

   - No significant change occurred in FC densities in Black Creek at Scarlett Road and Humber at Lakeshore Blvd.

   - The FC/FS ratios in Black Creek at Scarlett Road show an increasing trend since 1980 possibly due to fecal contamination by human and Group I waste sources. These are likely due to human-origin wastes from combined and other active sewer discharges as well as non-human animal (dog) wastes.

The following recommendations related to field studies, data analyses and interpretation are made:

1. A methodology should be developed to evaluate the effect of wet weather bacterial densities in interpreting the water quality objectives.

2. The number and location of monitoring stations should be selected by giving due consideration to the channel characteristics, waste source locations and other factors and processes, such as sediment deposition/resuspension which affect bacterial transport in streams and rivers.

3. It is recommended that the sediment phase be included in future studies to gather data on: (a) bacteriologically active sediment localities in stream beds and their quantification; and (b) densities of various bacteriological parameters of concern in the bed sediments. These data, in conjunction with those for the water phase, will permit detailed mass balance computations and thus aid in evaluating cause-and-effect relationships.

4. It is also recommended that future studies include data collection for estimating bacterial growth and die-off rates in water courses under natural environmental conditions. The die-off rates reported in the literature vary widely, making it somewhat difficult to rely on them. Instream die-off rates are reported in the literature for the coliform group of bacteria only, but no such data seem to be available in the literature for the other bacterial parameters associated with recreational water quality.

5. Since the sources of bacterial loadings to water courses constitute one of the most important data elements utilized in recreational bacteriological water quality assessment studies, it is recommended to consider the bacterial inputs from other possible sources such as water fowl, animals, etc., in the assessment studies.

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APPENDIX A

DRY AND WET WEATHER DATA SUMMARY

TABLE A1

DRY WEATHER DATA SUMMARY

HUMBER RIVER @ QUEENSWAY AVE. - STN. H1

EVENT	DATE 1983	WEATHER CONDITIONS	SAMPLE TIME (Hrs)	STAGE (m)	DISCHARGE (m^3/S)	TEMP ^oC	CONDUCTIVITY (umhos/cm)	BACTERIOLOGICAL PARAMETERS (counts/100 ml) FC	FS	ENT	EC	PA	COMMENTS
1	09.12	Cloudy & Warm	1210	1.83		17^0	450	360	16	8	300	4L	Surface cur. in dir. of river cur. Offshore winds
2	09.15	Sunny & Clear	0945	1.70		18^0	500	580	64	28	370	8	Floating algae Offshore surface cur.
3	09.25	Cloudy	1800	1.83		18^0	500	360	44	10	210	4	Onshore winds Upstream surface cur.
4	09.27	Overcast	1300	1.37		18^0	500	710	84	16	510	20	Offshore winds Downstream surface cur.
5	09.29	Sunny & Clear	1030	1.37		17^0	500	630	40	26	500	4	Quiescent
6	10.03	Sunny & Clear	1000	1.37		17^0	550	430	56	22	400	4	Onshore winds
7	10.11	Partly Cloudy	0945	1.37		13^0	450	630	216	16	320	32	Onshore winds
8	10.18	Cloudy & Cool	1100	1.37		12^0	470	1720	164	16	1440	36	Definite downstream Current
9	10.20	Sunny & Clear, Cold	1115	1.37		9^0	440	320	112	2L	230	4L	Onshore winds
10	10.25	Overcast	1345	1.37		10^0	390	1600	320	10	890	36L	Upstream cur.

R - APPROXIMATE RESULT; EXCEEDED NORMAL RANGE LIMIT
L - ACTUAL RESULT IS LESS THAN REPORTED VALUE

TABLE A2

DRY WEATHER DATA SUMMARY

HUMBER RIVER @ DUNDAS ST. WEST - STN. H2

EVENT	DATE 1983	WEATHER CONDITIONS	SAMPLE TIME (Hrs)	STAGE (m)	DISCHARGE (m^3/S)	TEMP ^0C	CONDUCTIVITY (umhos/cm)	BACTERIOLOGICAL PARAMETERS (counts/100 ml) FC	FS	ENT	EC	PA	COMMENTS
1	09.12	Cloudy & Sunny	1235	0.31		18^0	500	910	1700	20	520	4	@6 waterfowl upstream
2	09.15	Sunny & Clear	1015	0.34		19^0	500	950	100	26	670	4	" "
3	09.25	Cloudy	1830	0.31		18^0	490	550	124	26	390	8	@6-10 " "
4	09.27	Overcast	1330	0.28		18^0	500	600	56	2	330	4	" "
5	09.29	Sunny & Clear	1045	0.30		17^0	490	680	96	14	340	4	-
6	10.03	Sunny & Clear	1030	0.28		17^0	525	620	64	18	600	12	-
7	10.11	Sunny & Clear	1010	0.29		12^0	460	490	352	12	360	4L	-
8	10.18	Cloudy & Cool	1115	0.31		10.5^0	470	370	156	18	250	8	Few waterfowl upstream
9	10.20	Sunny & Clear	1145	0.29		8^0	450	370	148	4	170	4	-
10	10.25	Overcast	1410	0.32		9^0	410	1170	392	8	990	20	-

L - ACTUAL RESULT IS LESS THAN REPORTED VALUE

TABLE A3

DRY WEATHER DATA SUMMARY

HUMBER RIVER @ JAMES GARDENS - STN. H3

EVENT	DATE 1983	WEATHER CONDITIONS	SAMPLE TIME (Hrs)	STAGE (m)	DISCHARGE (m^3/S)	TEMP ^oC	CONDUCTIVITY (umhos/cm)	BACTERIOLOGICAL PARAMETERS (counts/100 ml) FC	FS	ENT	EC	PA	COMMENTS
1	09.12	Partly Cloudy	1420	0.37		17^0	450	940	1170	28	870	20	>12 Waterfowl upstream
2	09.15	Sunny & Clear	1110	0.43		17^0	450	820	180	46	690	8	" "
3	09.25	Overcast	1940	0.37		18^0	440	390	48	30	320	12	
4	09.27	Overcast	1410	0.31		18^0	430	430	36	2	190	8	" "
5	09.29	Sunny & Clear	1120	0.31		17^0	440	300	72	16	210	4L	" "
6	10.03	Sunny & Clear	1110	0.31		18^0	460	390	32	20	390	4L	" "
7	10.11	Sunny & Clear	1100	0.34		13^0	410	350	264	2	120	4	" "
8	10.18	Cloudy, Hazy Sun	1140	0.32		11^0	430	160	124	6	160	4	" "
9	10.20	Sunny & Clear	1240	0.34		10^0	390	150	188	2	150	4L	" "
10	10.25	Overcast	1440	0.34		9^0	390	910	268	6	540	12	" "

L - ACTUAL RESULT IS LESS THAN REPORTED VALUE

TABLE A4

DRY WEATHER DATA SUMMARY

HUMBER RIVER @ STEELES AVE. - STN. H4

EVENT	DATE 1983	WEATHER CONDITIONS	SAMPLE TIME (Hrs)	STAGE (m)	DISCHARGE* (m^3/S)	TEMP °C	CONDUCTIVITY (umhos/cm)	BACTERIOLOGICAL PARAMETERS (counts/100 ml) FC	FS	ENT	EC	PA	COMMENTS
1	09.12	Sunny & Clear	1500	0.17	0.947	18°	430	190	240	24	110	8	Water Murky
2	09.15	Sunny & Clear	1230	0.18	1.007	18°	450	100	32	2	30A	4L	"
3	09.25	Overcast	2015	0.15	1.668	18°	450	60A	112	8	20A	4L	"
4	09.27	Overcast	1500	0.21	1.507	17°	410	204	84	2L	64	4L	"
5	09.29	Sunny & Clear	1205	0.21	1.470	16°	400	180	52	2	124	4	"
6	10.03	Sunny & Clear	1145	0.21	1.371	17°	400	140	32	2L	104	4L	"
7	10.11	Hazy Sun	1150	0.23	1.737	12°	390	76	88	4	72	4L	"
8	10.18	Cloudy & Cool	1230	0.24	1.930	12°	390	104	44	2L	60	4	-
9	10.20	Sunny & Clear	1445	0.23	1.644	9°	370	44	236	4	16	4	Water Murky
10	10.25	Overcast	1515	0.29	2.924	8°	360	520	268	2L	540	4L	-

* - Approximated by summing upstream flow at Elder Mills and Pine Grove
A - APPROXIMATE RESULT
L - ACTUAL RESULT IS LESS THAN REPORTED VALUE

TABLE A5

DRY WEATHER DATA SUMMARY

BLACK CREEK @ SCARLET ROAD - STN. B1

EVENT	DATE 1983	WEATHER CONDITIONS	SAMPLE TIME (Hrs)	STAGE (m)	DISCHARGE (m^3/S)	TEMP ^{0}C	CONDUCTIVITY (umhos/cm)	BACTERIOLOGICAL PARAMETERS (counts/100 ml) FC	FS	ENT	EC	PA	COMMENTS
1	09.12	Sunny & Clear	1355	0.31	0.23	17^0	1300	4300	2100	112	2420	76	Floating debris Children in stream Upstream of location
2	09.15	Sunny & Clear	1051	0.17	0.062	17^0	1100	3800	460	120	3300	136	Dislodged algae & debris
3	09.25	Overcast	1915	0.31	0.23	19^0	1200	3600	2160	116	4000	80	-
4	09.27	Overcast	1340	0.29	0.192	18^0	1000	4900	220	40	2300	112	-
5	09.29	Sunny & Clear	1105	0.28	0.174	17^0	1200	16700B	460	296	9800	224	-
6	10.03	Sunny & Clear	1050	0.28	0.174	15^0	1400	7100	880	232	7200	96	-
7	10.11	Sunny & Clear	1045	0.28	0.174	14^0	1100	5900	680	76	3900	56	-
8	10.18	Cloudy & Cool	1125	0.31	0.230	12^0	1000	2200	340	64	1260	88	-
9	10.20	Sunny & Clear	1210	0.29	0.192	11^0	1100	1400	100A	12	780	20	-
10	10.25	Overcast	1425	0.34	0.296	11.5^0	900	6100	470	96	1400	140	-

B - APPROXIMATE RESULT; EXCEEDED NORMAL RANGE LIMIT
A - APPROXIMATE RESULT

TABLE A6

DRY WEATHER DATA SUMMARY

BLACK CREEK @ LAWRENCE AVE. - STN. B2

EVENT	DATE 1983	WEATHER CONDITIONS	SAMPLE TIME (Hrs)	STAGE (m)	DISCHARGE (m^3/S)	TEMP ^0C	CONDUCTIVITY (umhos/cm)	BACTERIOLOGICAL PARAMETERS (counts/100 ml) FC	FS	ENT	EC	PA	COMMENTS
1	09.12	Partly Cloudy	1435	0.10	0.045	17^0	1000	1980	1820	8	1440	40	Debris in creek (foodstuffs)
2	09.15	Sunny & Clear	1155	0.10	0.045	17^0	1000	180A	250	10	360	52	-
3	09.25	Overcast	1950	0.12	0.068	19^0	900	1200	970	72	1130	88	-
4	09.27	Hazy Sun	1430	0.13	0.081	18^0	730	2420	300	14	1820	76	-
5	09.29	Sunny & Clear	1145	0.11	0.056	17^0	900	1860	520	152	1060	68	-
6	10.03	Sunny & Clear	1125	0.10	0.045	18^0	1000	600	100A	44	460	40	-
7	10.11	Sunny & Clear	1120	0.11	0.056	14^0	800	820	1300	28	640	76	-
8	10.18	Cloudy & Cool	1200	0.14	0.096	12^0	800	2260	360	96	1340	128	-
9	10.20	Sunny & Clear	1330	0.14	0.096	12^0	880	800	260	16	820	268	-
10	10.25	Overcast	1455	0.16	0.130	10^0	800	7100	2100	136	4400	592B	-

A - APPROXIMATE RESULT
B - APPROXIMATE RESULT; TOTAL EXCEEDS 300 COLONIES

TABLE A7

WET WEATHER DATA SUMMARY

OCTOBER 3-4 1983 SURVEY

HUMBER RIVER @ DUNDAS ST. WEST - STN. H2

Date Oct. 1983	Time (EDT)	Stage (m)	Discharge (m^3)	Temperature $^{\circ}C$	Conductivity umho/cm	Bacteriological Parameters (Counts/100 ml) FC	FS	ENT	EC	PA	FC/FS	Remarks
03	2045	0.27		20°	-	1030	350	200	1070	30A	2.94	
03	2210	0.27		20°	500	6100	4500	2700	5100	290	1.36	
03	2340	0.37		18.5°	575	150000	93000	47000	121000	8100	1.61	
04	0200	0.37		18°	600	134000	101000	200000	7900	810B	1.33	
04	0510	0.26		18°	600	53000	39000	7900	34000	830B	1.36	
04	0723	0.29		18°	500	14100	5700	10600	9600	570	2.47	
04	0910	0.29		18°	500	6100	980	1540	4300	290	6.22	
04	1130	0.29		19°	525	4100	1260	480	3800	220	3.25	
04	1345	0.27		20°	550	3800	360	260	2300	140	10.56	Waterfowl Upstream

B - APPROXIMATE RESULT; TOTAL COUNT EXCEEDS 300 COLONIES

TABLE A8

WET WEATHER DATA SUMMARY

OCTOBER 3-4 1983 SURVEY

HUMBER RIVER @ JAMES GARDENS - STN. H3

Date Oct. 1983	Time (EDT)	Stage (m)	Discharge (m^3)	Temperature ^oC	Conductivity umho/cm	Bacteriological Parameters (Counts/100 ml) FC	FS	ENT	EC	PA	FC/FS	Remarks
03	2110	0.40		18^o	460	5400	11000	350	3300	40A	0.49	
03	2310	0.43		18^o	440	9100	81000	3100	6900	290	0.11	
04	0045	0.40		18^o	480	12600	8300	4800	9100	490	1.52	
04	0405	0.34		17.5^o	470	6800	5500	2700	3800	130	1.24	
04	0655	0.34		17.5^o	450	5100	2500	1600	4500	90A	2.04	
04	0830	0.32		18^o	450	2180	940	820	2180	60A	2.32	
04	1140	0.31		19.5^o	480	1420	380	300	1040	90A	3.74	Waterfowl
04	1355	0.31		20^o	480	1320	120A	100A	1060	50A	11.00	Upstream

A - APPROXIMATE RESULT

TABLE A9

WET WEATHER DATA SUMMARY

OCTOBER 3-4 1983 SURVEY

BLACK CREEK @ SCARLETT ROAD - STN. B1

Date Oct. 1983	Time (EDT)	Stage (m)	Discharge (m^3)	Temperature ^0C	Conductivity umho/cm	Bacteriological Parameters (Counts/100 ml) FC	FS	ENT	EC	PA	FC/FS	Remarks
03	2100	0.37	0.373	19^0	1100	21000	25000	4000A	13000	500A	0.84	
03	2130	0.46	0.650	19^0	975	1900000	500000	360000	1420000	23000	3.80	River like
03	2230	0.49	0.763	19^0	800	111000	640000	25000	50000	6300	0.17	'OPEN
03	2300	0.56	1.040	19^0	825	220000	138000	22000	104000	2200	1.59	SEWER'
03	2330	0.61	1.270	19^0	875	123000	99000	21000	94000	2500	1.24	
04	0120	0.53	0.920	18^0	750	61000	39000	18000	30000	1500	1.56	
04	0430	0.37	0.373	17.5^0	720	68000	52000	76000	35000	2300	1.31	
04	0645	0.37	0.373	18^0	750	46000	39000	16000	31000	1900	1.18	
04	0850	0.32	0.250	18.5^0	825	21000	7900	5900	23000	2900	2.66	
04	0940	0.31	0.230	18^0	900	24000	5800	4700	17000	2100	4.14	
04	1105	0.31	0.230	19^0	1000	25000	4900	1600	18000	780	5.10	
04	1155	0.31	0.230	20^0	1000	26000	2900	1100	13000	810	8.97	
04	1310	0.31	0.230	20^0	1000	33000	1900	800A	19000	990	17.37	
04	1410	0.31	0.230	20^0	1000	10000	900A	300A	12000	630	11.11	

A - APPROXIMATE RESULT

TABLE A10

WET WEATHER DATA SUMMARY

OCTOBER 3-4 1983 SURVEY

BLACK CREEK @ LAWRENCE AVE. STN. B2

Date Oct. 1983	Time (EDT)	Stage (m)	Discharge (m^3)	Temperature ^{0}C	Conductivity umho/cm	Bacteriological Parameters (Counts/100 ml) FC	FS	ENT	EC	PA	FC/FS	Remarks
03	2135	0.39	0.962	18^0	950	24000	47000	1300	8000	300	0.51	
03	2205	0.33	0.660	18^0	800	49000	134000	36000	22000	2700	0.37	
03	2235	0.31	0.574	18^0	700	42000	250000	19000	12000	3100	0.17	
03	2330	0.31	0.574	18^0	620	48000	139000	85000	19000	2100	0.35	
03	2400	0.31	0.574	18^0	650	42000	53000	90000	42000	2700	0.79	
04	0030	0.30	0.533	18^0	650	43000	52000	38000	31000	2100	0.83	
04	0335	0.23	0.293	18^0	750	36000	67000	14000	24000	1200	0.54	
04	0630	0.16	0.130	17.5^0	650	41000	83000	17000	15000	1000	0.49	
04	0800	0.15	0.112	18^0	700	10000	66000	4100	18000	390	0.15	
04	0945	1.14	0.096	18^0	750	27000	71000	2200	17000	590	0.38	
04	1050	0.14	0.096	18^0	750	14000	57000	1900	16000	610	0.25	
04	1210	0.14	0.096	20^0	800	13000	23000	900A	14000	330	0.57	
04	1300	0.15	0.112	19^0	800	11000	26000	1200	22000	370	0.42	
04	1425	0.14	0.096	19^0	800	22000	7400	1200	11000	490	2.97	

A - APPROXIMATE RESULT

TABLE A11

WET WEATHER DATA SUMMARY

NOVEMBER 15-17 1984 SURVEY

HUMBER RIVER @ DUNDAS ST. WEST - STN. H2

Date Nov. 1983	Time (EST)	Stage (m)	Discharge (m^3)	Temperature ^oC	Conductivity umho/cm	Bacteriological Parameters (Counts/100 ml) FC	FS	ENT	EC	PA	FC/FS	Remarks
15	1300	0.31		5^o	420	4200	840	620	1180	50A	5.00	
15	1340	0.33		5^o	450	1820	620	300	1120	10A	2.94	
15	1825	0.49		ND	ND	13000	6100	5700	9800	500	2.13	
15	2050	0.55		ND	ND	34000	6300	7300	20000	900A	5.40	
16	0145	0.37		5.5^o	260	10300	9000	14000	8000	600	1.14	Water
16	0340	0.37		5.5^o	245	5300	6800	21000	4800	340	0.78	Extremely
16	0740	0.37		5.5^o	240	37000	9600	22000	23000	960	3.85	Silty
16	0940	0.37		6^o	250	23000	20000	11000	14600	540	1.15	
16	1300	0.37		7^o	300	9600	9600	5900	6400	400	1.00	
17	0920	0.53		3^o	420	1740	2360	860	1140	50A	0.74	

ND - NO DATA
A - APPROXIMATE RESULT

TABLE A12

WET WEATHER DATA SUMMARY

NOVEMBER 15-17 1983 SURVEY

HUMBER RIVER @ JAMES GARDEN - STN. H3

Date Nov. 1983	Time (EST)	Stage (m)	Discharge (m^3)	Temperature ^0C	Conductivity umho/cm	Bacteriological Parameters (Counts/100 ml)						Remarks
						FC	FS	ENT	EC	PA	FC/FS	
15	1340	0.31		3^0	380	700	60A	80A	360	10L	11.67	
15	1525	0.34		4^0	400	1520	880	1100	700	60A	1.73	
15	1730	0.40		ND	ND	5100	1080	1620	4400	110	4.72	
15	2020	0.52		ND	ND	9500	2020	4300	5900	190	4.70	
16	0100	0.61		5^0	280	8700	10600	8300	5400	520	0.82	
16	0300	0.55		5^0	260	2800	6000	9000A	1900	380	0.47	
16	0750	0.55		5^0	260	5700	5600	10000	7900	380	1.02	
16	0950	0.55		5^0	270	6900	4500	11000	7700	440	1.53	
16	1245	0.55		6^0	300	6000	9400	6000	5200	340	0.64	
17	0940	0.38		3^0	420	1140	2500	680	720	40A	0.46	

ND - NO DATA
L - ACTUAL RESULT IS LESS THAN THE REPORTED VALUE
A - APPROXIMATE RESULT

TABLE A13

WET WEATHER DATA SUMMARY

NOVEMBER 15-17 1983 SURVEY

BLACK CREEK @ SCARLETT ROAD - STN. B1

Date Nov. 1983	Time (EST)	Stage (m)	Discharge (m^3)	Temperature °C	Conductivity umho/cm	Bacteriological Parameters (Counts/100 ml) FC	FS	ENT	EC	PA	FC/FS	Remarks
15	1325	0.46	0.650	7^o	1000	4900	1700	1300	3800	240	2.88	
15	1345	0.46	0.650	7^o	1100	6100	4800	12000	4700	220	1.27	
15	1405	0.48	0.725	7^o	1250	116000	15000	31000	117000	860	7.73	
15	1435	0.53	0.920	7^o	1300	32000	21000	23000	44000	700	1.52	
15	1505	0.66	1.530	7^o	1100	12900	3900	3200	10700	420	3.31	
15	1535	0.69	1.720	7^o	1000	47000	6700	6100	48000	880	7.01	
15	1800	0.79	2.510	ND	ND	25000	13000	20000	13000	1100	1.92	
15	2040	1.10	10.600	ND	ND	45000	17000	35000	35000	2700	2.65	
15	2140	1.10	10.600	ND	ND	33000	23000	16000	31000	1900	1.43	
16	0200	1.01	7.450	5.5^o	240	7400	12700	14000	5700	520	0.58	
16	0350	0.94	5.480	5.5^o	235	3800	10700	19000	3200	520	0.36	
16	0715	1.20	14.500	6^o	200	33000	25000	29000	40000	660	1.32	
16	0930	0.91	4.670	6^o	260	16000	11600	18000	9800	620	1.38	
16	1105	0.91	4.670	6.5^o	290	7400	9500	11000	6500	440	0.78	
16	1230	0.91	4.670	7^o	320	7300	9600	16000	4600	660	0.76	
17	0900	0.61	1.270	4^o	900	6400	7800	6800	5100	190	0.82	

ND - NO DATA

TABLE A14

WET WEATHER DATA SUMMARY

NOVEMBER 15-17 1983 SURVEY

BLACK CREEK @ LAWRENCE AVE. - STN. B2

Date Nov. 1983	Time (EST)	Stage (m)	Discharge (m^3)	Temperature ^oC	Conductivity umho/cm	Bacteriological Parameters (Counts/100 ml) FC	FS	ENT	EC	PA	FC/FS	Remarks
15	1315	0.22	0.270	6.5^o	1200	2300	900A	700A	1900	120A	2.56	
15	1400	0.34	0.706	6.5^o	1100	4200	1000	800A	3000	120A	4.20	
15	1430	0.38	0.907	7^o	1300	3600	1900	2000	3700	300	1.89	
15	1500	0.39	0.962	7^o	2300	4500	3800	3600	5000	260	1.18	
15	1550	0.48	1.534	7^o	1900	2900	4300	3000	1900	420	0.67	
15	1705	0.54	1.990	5.5^o	1325	6000	4400	4200	4000	460	1.36	
15	2000	0.80	4.842	ND	ND	4900	7600	6200	4300	760	0.64	
15	2130	0.90	6.312	ND	ND	5600	5500	5300	2800	620	1.02	
15	2200	0.95	7.128	ND	ND	6000	5300	5100	2900	440	1.13	
16	0125	0.86	5.698	5.5^o	225	4800	7600	24000	3000	860	0.63	
16	0325	0.80	4.842	5.5^o	230	4700	9500	10000	1900	680	0.49	
16	0820	0.85	5.550	6^o	250	6600	7300	19000	5600	560	0.90	
16	1010	0.75	4.188	6^o	280	8300	11400	8200	4700	500	0.73	
16	1130	0.70	3.586	-	-	14500	8000	9100	10000	460	1.81	
16	1320	0.65	3.035	6^o	340	8400	11000	7100	7200	620	0.76	
17	0840	0.34	0.706	4^o	1600	4100	8500	2200	2600	160	0.48	

ND - NO DATA
A - APPROXIMATE RESULT

APPENDIX B

METEOROLOGICAL AND STREAMFLOW DATA SUMMARY

TABLE B1

DAILY METEOROLOGICAL DATA SUMMARIES FOR AUGUST - OCTOBER 1983

KEELE - FINCH STATION

AUGUST 1983

DATE	TOTAL RAINFALL(MM)
03	5.0
05	0.2
08	13.1
09	0.0
10	7.6
11	9.8
21	10.6
22	0.6
27	17.0
28	0.0
29	1.0
30	7.8

OCTOBER 1983

DATE	TOTAL RAINFALL(MM)
03	4.0
04	17.9
05	4.6
08	9.1
11	16.0
12	7.6
13	14.0
16	2.8
22	15.0

NOTE: TEMPERATURE NOT RECORDED
NO DATA FOR SEPTEMBER 1983

TABLE B1 (CONTD.)

TORONTO ISLAND AIRPORT STATION

DATE	AUGUST 1983 MEAN TEMP(°C)	AUGUST 1983 TOTAL RAIN(MM)	SEPTEMBER 1993 MEAN TEMP(°C)	SEPTEMBER 1993 TOTAL RAIN(MM)	OCTOBER 1993 MEAN TEMP(°C)	OCTOBER 1993 TOTAL RAIN(MM)
1	22.4	0.8	21.3		16.0	
2	23.3		21.4		15.6	
3	23.0		22.6		18.8	4.0
4	22.4	2.0	23.9		17.9	5.4
5	24.4		24.7		13.9	7.0
6	25.0		24.9	1.8	14.7	0.2
7	25.7	TR	20.7		11.7	
8	26.0	14.0	19.4		11.8	7.1
9	20.3		19.9	1.8	8.4	
10	18.6		24.9	0.2	9.9	
11	17.3	16.8	19.7		14.9	TR
12	20.2		17.3		14.7	24.2
13	19.3		15.2		15.8	17.2
14	20.2		15.0		9.5	0.4
15	21.5	0.2	14.7		10.9	
16	22.5		15.1	15.0	8.4	0.6
17	22.3		16.6		12.5	
18	24.5	0.2	15.8	5.4	10.8	
19	23.1	TR	20.2	TR	6.6	
20	24.9		21.4	0.2	5.5	
21	20.9	1.0	16.1	11.8	6.9	
22	21.8	28.2	11.6	0.3	8.6	0.6
23	20.7		11.3	0.2	8.9	20.0
24	21.1		11.6		8.3	TR
25	21.5		13.5	1.4	8.9	TR
26	23.9		15.1	0.6	8.3	TR
27	25.5	3.4	15.2		6.2	
28	23.2	TR	12.8		13.4	TR
29	24.4		14.2		4.2	TR
30	22.2	10.7	14.6		3.9	
31	23.2		N/A	N/A	5.4	

TR = TRACE
N/A = NOT APPLICABLE

TABLE B1 (CONTD.)

BLOOR STREET STATION (TORONTO CITY)

DATE	AUGUST 1983 MEAN TEMP(°C)	AUGUST 1983 TOTAL RAIN(MM)	SEPTEMBER 1983 MEAN TEMP(°C)	SEPTEMBER 1983 TOTAL RAIN(MM)	OCTOBER 1983 MEAN TEMP(°C)	OCTOBER 1983 TOTAL RAIN(MM)
1	22.9		21.4		17.2	
2	23.4		21.0		17.3	
3	22.9	1.8	22.4		19.8	4.8
4	23.1	TR	23.8		19.6	2.2
5	24.6	0.2	25.3		14.8	6.4
6	25.0		25.6	4.4	14.3	
7	25.8		20.9		11.2	0.2
8	28.0	22.2	19.4		13.6	7.8
9	20.5		21.9	0.5	7.8	
10	17.5	4.4	27.3		8.4	
11	16.1	15.5	23.7		14.3	18.2
12	19.8		18.7	TR	14.6	7.8
13	19.3		16.4		18.5	18.6
14	19.8		14.9		11.7	TR
15	21.2	TR	14.3	0.6	10.9	
16	22.4		14.6	18.6	7.7	0.6
17	22.6		16.5		11.9	
18	25.0		16.0	4.6	11.3	
19	23.3	TR	20.9		6.3	
20	26.2		22.6	6.8	5.0	
21	20.0	30.4	14.8	4.8	5.9	
22	21.3	0.2	10.7	0.4	7.6	11.8
23	20.6		10.8	0.6	8.9	8.2
24	20.7		11.5		8.1	
25	21.5		13.5	3.0	8.0	0.2
26	24.2		16.2		8.0	TR
27	24.9	23.6	16.3		6.7	TR
28	23.2	TR	15.6		13.4	
29	24.1		14.9		5.5	
30	22.0	4.8	16.0		3.5	
31	22.6		N/A	N/A	5.3	

TABLE 81 (CONTD.)

AMESBURY PARK STATION

AUGUST 1983

DATE	TOTAL RAIN(MM)
3	2.4
4	0.0
8	29.9
10	13.0
11	12.4
12	0.0
21	21.0
25	0.0
26	0.0
27	4.4
29	0.0
30	5.3

SEPTEMBER 1983

DATE	TOTAL RAIN(MM)
15	3.8
16	30.0
25	3.0

OCTOBER 1983

DATE	TOTAL RAIN(MM)
3	4.2
4	3.4
5	4.6

NOTE: TEMPERATURE NOT RECORDED

TABLE B1 (CONTD.)

BOLTON WPCP STATION

DATE	AUGUST 1983 MEAN TEMP(C)	AUGUST 1983 TOTAL RAIN(MM)	SEPTEMBER 1993 MEAN TEMP(C)	SEPTEMBER 1993 TOTAL RAIN(MM)	OCTOBER 1993 MEAN TEMP(C)	OCTOBER 1993 TOTAL RAIN(MM)
1	22.9	13.8				
2	21.0					
3	20.9	2.6				
4	22.5	0.2				
5	23.5					
6	23.3		22.0	2.4		
7	24.0					
8	24.9	0.8				
9	18.3					
10	14.0	10.2				
11	15.0	0.4				
12	18.0					
13	16.3					
14	17.5					
15	20.0		10.5	2.6		
16	20.5		12.5	27.0		
17	20.5					
18	23.0		13.8	15.4		
19	21.5					
20	23.9		20.3	13.4		
21	17.5	22.2	14.0	1.4		
22	19.0					
23	19.0		8.0	1.8		
24	17.5					
25	19.5		9.3	2.6		
26	22.9					
27	22.9					
28	22.5	17.0				
29	22.9	1.4				
30	20.9	11.6				
31	21.3					

NOTE: NO DATA FOR OCTOBER 1983

TABLE B1 (CONTD.)

TORONTO INTERNATIONAL AIRPORT STATION

DATE	AUGUST 1983 MEAN TEMP(°C)	AUGUST 1983 TOTAL RAIN(MM)	SEPTEMBER 1983 MEAN TEMP(°C)	SEPTEMBER 1983 TOTAL RAIN(MM)	OCTOBER 1983 MEAN TEMP(°C)	OCTOBER 1983 TOTAL RAIN(MM)
1	22.7	0.8	18.9		14.8	
2	22.0		19.9		16.0	
3	21.8	TR	21.8		20.8	4.8
4	22.6	3.2	23.1		17.3	2.0
5	23.7	1.6	24.4		11.8	4.2
6	24.9		23.9	1.0	11.0	TR
7	24.6		18.3		9.2	TR
8	25.4	29.6	18.1		9.8	7.2
9	17.3		21.5	0.2	6.3	
10	15.1		27.4	TR	6.7	
11	15.6	25.8	19.4	TR	14.1	TR
12	18.3		16.4		14.5	19.3
13	16.7		13.6	TR	15.0	12.2
14	17.9		11.9		7.5	2.2
15	20.4	TR	11.3		7.9	
16	20.9		14.1	28.9	6.4	2.4
17	22.0		14.1		10.2	
18	22.6		15.9	7.8	9.2	
19	22.5	TR	19.2		4.6	
20	21.3		21.9	2.0	4.3	
21	18.1	1.6	16.2	12.8	4.4	
22	20.9	28.4	9.2	0.2	5.3	0.8
23	20.0		9.0	0.2	7.8	16.5
24	19.5		10.2		5.7	TR
25	20.3		10.6	1.6	7.4	TR
26	23.9		15.2	0.2	6.2	0.2
27	24.9	1.2	14.5		3.7	TR
28	22.4	0.6	14.0		11.8	TR
29	23.4		13.1		1.4	TR
30	20.4	19.4	14.4		1.6	
31	20.7		N/A	N/A	3.0	

TABLE B2
DETAILED PRECIPITATION DATA FOR WET WEATHER PERIODS

(A) OCTOBER 3-4, 1983

DATE	HOUR (EDT)	RAINFALL(MM) AT STATED LOCATION			
		KEELE FINCH	TORONTO ISLAND AIRPORT	BLOOR STREET	AMESBURY PARK
OCT. 3	1800	0.8			
	1900	0.8			
	2000	1.6	3.0	2.6	
	2100		0.4	0.4	
	2200	1.6	0.4	1.7	2.0
	2300				
	2400				1.2
OCT. 4	100		0.2		
	200				
	300				
	400				
	500				
	600				
	700				
	800				
	900				
	1000				
	1100				
	1200				
	1300				
	1400	16.4		0.4	
	1500		0.4		
	1600		0.2	1.0	
	1700				0.6
	1800		4.4	0.6	
	1900	1.0	0.2	0.2	2.8
	2000		0.2		
	2100				
	2200				
	2300				
	2400				

TABLE B2 (CONTD.)

(B) NOVEMBER 15-16, 1983

DATE	HOUR (EST)	HOURLY RAINFALL(MM) AT TORONTO INTERNATIONAL AIRPORT
NOV. 15	1200	
	1300	1.2
	1400	0.6
	1500	1.2
	1600	1.5
	1700	1.2
	1800	1.9
	1900	1.7
	2000	2.3
	2100	2.3
	2200	1.9
	2300	1.3
	2400	1.9
NOV. 16	0100	1.0
	0200	NO DATA
	0300	NO DATA
	0400	1.0
	0500	1.2
	0600	2.3
	0700	2.7
	0800	1.2
	0900	1.0
	1000	0.8
	1100	0.4
	1200	0.6
	1300	0.6
	1400	
	1500	
	1600	

TABLE B3
DAILY SUMMARIES OF STREAMFLOWS

DATE	DISCHARGE (M^3/S) IN HUMBER RIVER AT WESTON ROAD (GAUGING STATION 02HC003) SEPTEMBER	OCTOBER	DISCHARGE (M^3/S) IN BLACK CREEK AT SCARLETT ROAD (GAUGING STATION 02HC027) SEPTEMBER	OCTOBER
1		1.690		0.187
2		1.650		0.203
3		1.730		0.322
4		3.190		0.836
5		2.750		0.736
6		2.230		0.395
7		2.020		0.278
8		2.810		0.860
9		2.290		0.282
10		2.130		0.197
11		2.110		0.196
12	1.190	5.190	0.105	2.200
13	1.120	5.430	0.114	1.930
14	1.080	5.890	0.116	0.774
15	1.150	4.381	0.114	0.390
16	2.270	3.470	1.880	0.446
17	3.260	3.070	0.454	0.448
18	3.110	2.600	0.759	0.320
19	2.850	2.360	0.205	0.285
20	2.750	2.170	0.257	0.242
21	3.650	2.090	1.060	0.234
22	3.070	2.060	0.315	0.224
23	2.790	4.690	0.282	2.020
24	2.270	4.130	0.214	0.451
25	2.080	4.190	0.201	0.325
26	2.150	3.470	0.359	0.301
27	1.980	3.030	0.230	0.275
28	1.860	2.750	0.220	0.271
29	1.790	2.560	0.222	0.230
30	1.790	2.360	0.218	0.226
31		2.290		0.234

NOTE: SAMPLING STARTED SEPTEMBER 12, 1983

TABLE B4

DETAILED STREAMFLOW DATA FOR WET WEATHER PERIODS

(A) OCTOBER 3-4, 1983

DATE	HOUR (EDT)	DISCHARGE (M^3/S) HUMBER RIVER @ WESTON RD.	BLACK CREEK @ SCARLETT RD.
OCT. 3	1800	1.670	0.192
	1900	1.670	0.402
	2000	1.710	0.627
	2100	1.880	1.020
	2200	2.000	1.520
	2300	2.020	1.080
	2400	2.130	0.766
OCT. 4	0100	2.230	0.618
	0200	2.230	0.520
	0300	2.230	0.454
	0400	2.170	0.419
	0500	2.040	0.388
	0600	1.940	0.339
	0700	1.880	0.308
	0800	1.840	0.294
	0900	1.820	0.278
	1000	1.810	0.273
	1100	1.810	0.275
	1200	1.790	0.285
	1300	1.790	0.291
	1400	1.790	0.665
	1500	4.790	1.880
	1600	12.700	3.090
	1700	10.400	4.050
	1800	7.340	4.590
	1900	6.520	2.780
	2000	5.560	1.850
	2100	4.570	1.370
	2200	3.820	1.020
	2300	3.420	0.820
	2400	3.150	0.669

TABLE B4 (CONTD.)

(B) NOVEMBER 15 -17, 1983

DATE	HOUR (EDT)	DISCHARGE (M^3/S) HUMBER RIVER @ WESTON RD.	BLACK CREEK @ SCARLETT RD.
NOV. 15	1300	3.260	0.415
	1400	3.280	0.542
	1500	3.690	1.190
	1600	4.240	2.020
	1700	4.850	3.390
	1800	5.550	6.230
	1900	6.540	8.840
	2000	7.870	10.000
	2100	9.400	11.600
	2200	11.100	13.600
	2300	12.900	12.200
	2400	13.500	9.910
NOV. 16	0100	14.000	10.200
	0200	14.300	9.520
	0300	14.300	9.110
	0400	14.400	7.890
	0500	14.500	6.960
	0600	14.600	9.420
	0700	15.400	13.300
	0800	15.700	12.800
	0900	14.800	9.620
	1000	13.900	6.890
	1100	13.100	5.860
	1200	12.200	4.910
	1300	12.200	4.670
	1400	12.200	4.520
	1500	12.200	5.360
	1600	12.300	5.230
	1700	12.500	4.410
	1800	12.800	3.690
	1900	13.000	3.200
	2000	13.300	2.790
	2100	13.500	2.540
	2200	13.700	2.440
	2300	13.700	2.350
	2400	13.700	2.140
NOV. 17	0100	13.800	1.890
	0200	13.800	1.700
	0300	13.800	1.540
	0400	13.800	1.400
	0500	13.900	1.280
	0600	13.900	1.200
	0700	13.900	1.120
	0800	13.900	1.090
	0900	13.800	1.080
	1000	13.800	1.060

NOTE: DATA IS PROVISIONAL AS INDICATED BY ENVIRONMENT CANADA

APPENDIX C

SUMMARY OF DATA FROM PREVIOUS STUDIES

TABLE C1

HISTORICAL WATER QUALITY DATA

HUMBER RIVER AT BOLTON STN. -1977

DAY	MONTH	FC	FS	PRCP	FC/FS
17	5	3000.00	120.00	3.05	25.00
16	6	12000.00	2200.00	0.00	5.45
14	7	3800.00	720.00	0.00	5.28
16	8	3200.00	164.00	5.70	19.51
15	9	-77.00	1310.00	14.90	-77.00
17	10	7300.00	1200.00	6.45	6.08
GEOMEAN:		5022.37	604.93		
NDT:		5	6		
DRY GEOMEAN:		6752.73	1258.56		5.37
NDT:		2	2		
WET GEOMEAN:		4122.82	419.39		
NDT:		3	4		

HUMBER RIVER AT BOLTON STN. -1978

DAY	MONTH	FC	FS	PRCP	FC/FS
17	5	1200.00	90.00	3.50	13.33
15	6	840.00	600.00	0.00	1.40
17	7	3300.00	310.00	0.00	10.65
25	8	26000.00	-77.00	15.10	-77.00
18	9	1400.00	500.00	44.00	2.80
GEOMEAN:		2609.82	302.47		
NDT:		5	4		
DRY GEOMEAN:		1664.92	431.27		3.86
NDT:		2	2		
WET GEOMEAN:		3521.74	212.13		
NDT:		3	2		

HUMBER RIVER AT BOLTON STN. -1979

DAY	MONTH	FC	FS	PRCP	FC/FS
25	6	*70.00	-77.00	0.00	-77.00
1	8	280.00	110.00	29.60	2.55
27	8	*80.00	40.00	6.50	2.00
10	10	200.00	390.00	21.00	0.51
GEOMEAN:		133.07	119.72		
NDT:		4	3		
DRY GEOMEAN:		70.00	-99.00		-99.00
NDT:		1	0		
WET GEOMEAN:		164.85	119.72		
NDT:		3	3		

HUMBER RIVER AT BOLTON STN. -1990

DAY	MONTH	FC	FS	PRCP	FC/FS
17	6	260.00	330.00	0.00	0.79
3	10	* 90.00	*160.00	26.10	0.56
GEOMEAN:		152.97	229.78		
NDT:		2	2		
DRY GEOMEAN:		260.00	330.00		0.79
NDT:		1	1		
WET GEOMEAN:		90.00	160.00		
NDT:		1	1		

HUMBER RIVER AT BOLTON STN. -1991

DAY	MONTH	FC	FS	PRCP	FC/FS
12	5	450.00	600.00	24.05	0.75
30	6	*80.00	150.00	2.80	0.53
26	8	40.00	150.00	0.00	0.27
28	9	-77.00	120.00	2.75	-77.00
GEOMEAN:		112.92	200.62		
NDT:		3	4		
DRY GEOMEAN:		56.57	139.25		0.41
NDT:		2	3		
WET GEOMEAN:		450.00	600.00		
NDT:		1	1		

-77. : DATA REPORTED AS LESS THAN OR GREATER THAN AND NOT USED
-99. : DATA NOT AVAILABLE
FC: FECAL COLIFORMS (COUNTS/100 ML)
FS: FECAL STREPTOCOCCI (COUNTS/100 ML)
PA: PSUEDOMONAS AERUGINOSA (COUNTS/100 ML)
PRCP: MILLIMETERS OF PRECIPITATION FOR DAY OF SAMPLING PLUS 2 DAYS PREVIOUS - AVERAGE OF OLD WESTON RD. AND KEELE-FINCH STNS.
* : APPROXIMATE VALUE

TABLE C1 (CONTD.)

HUMBER RIVER AT LAKESHORE BLVD STN. -1977

DAY	MONTH	FC	FS	PRCP	FC/FS
17	5	1500.00	90.00	3.05	16.67
15	6	1400.00	-77.00	0.00	-77.00
14	7	210.00	30.00	0.00	7.00
20	7	270.00	30.00	0.90	9.00
9	8	4100.00	2100.00	22.15	1.95
16	8	1400.00	370.00	5.70	3.78
15	9	310.00	90.00	14.90	3.44
11	10	270.00	630.00	2.40	0.43
17	10	260.00	330.00	6.45	0.79
GEOMEAN:		626.51	181.50		
NDT:		9	8		
DRY GEOMEAN:		392.62	82.77		4.62
NDT:		4	3		
WET GEOMEAN:		929.53	290.72		
NDT:		5	5		

HUMBER RIVER AT LAKESHORE BLVD. STN. -1978

DAY	MONTH	FC	FS	PRCP	FC/FS
9	5	2000.00	-77.00	11.20	-77.00
17	5	1880.00	1420.00	3.50	1.32
6	6	-77.00	50.00	2.45	-77.00
15	6	340.00	130.00	0.00	2.62
6	7	700.00	20.00	0.00	35.00
17	7	140.00	100.00	0.00	1.40
9	8	620.00	430.00	5.30	1.44
23	8	1480.00	100.00	15.10	14.80
14	9	-77.00	900.00	18.50	-77.00
18	9	35000.00	16000.00	44.00	2.19
GEOMEAN:		1190.07	282.42		
NDT:		8	9		
DRY GEOMEAN:		321.78	60.05		5.36
NDT:		3	4		
WET GEOMEAN:		2608.42	974.59		
NDT:		5	5		

HUMBER RIVER AT LAKESHORE BLVD. STN. -1979

DAY	MONTH	FC	FS	PRCP	FC/FS
14	6	450.00	360.00	0.00	1.25
4	7	160.00	130.00	0.00	1.23
14	8	270.00	*40.00	2.30	6.75
6	9	200.00	*70.00	0.90	2.86
25	10	1400.00	-99.00	0.45	-99.00
30	10	1000.00	1000.00	0.00	1.00
GEOMEAN:		419.41	167.29		
NDT:		6	5		
DRY GEOMEAN:		419.41	167.29		2.51
NDT:		6	5		
WET GEOMEAN:		-99.00	-99.00		
NDT:		0	0		

HUMBER RIVER AT LAKESHORE BLVD. STN. -1980

DAY	MONTH	FC	FS	PRCP	FC/FS
6	5	520.00	340.00	3.50	1.53
4	7	250.00	* 30.00	0.00	8.33
2	9	5200.00	-99.00	6.30	-99.00
10	9	2500.00	1400.00	4.10	1.79
2	10	*4000.00	1700.00	12.70	2.35
GEOMEAN:		1465.50	394.72		
NDT:		5	4		
DRY GEOMEAN:		250.00	30.00		8.33
NDT:		1	1		
WET GEOMEAN:		2280.34	931.86		
NDT:		4	3		

HUMBER RIVER AT LAKESHORE BLVD. STN. -1981

DAY	MONTH	FC	FS	PRCP	FC/FS
7	5	310.00	70.00	5.50	4.43
10	6	650.00	1160.00	13.70	0.56
8	7	570.00	140.00	0.00	4.07
7	8	500.00	220.00	0.50	2.27
10	9	1400.00	390.00	3.10	3.59
16	10	1700.00	690.00	5.40	2.46
GEOMEAN:		717.71	296.03		
NDT:		6	6		
DRY GEOMEAN:		533.85	175.50		3.04
NDT:		2	2		
WET GEOMEAN:		832.17	384.47		
NDT:		4	4		

-77. : DATA REPORTED AS LESS THAN OR GREATER THAN AND NOT USED
-99. : DATA NOT AVAILABLE
FC: FECAL COLIFORMS (COUNTS/100 ML)
FS: FECAL STREPTOCOCCI (COUNTS/100 ML)
PA: PSUEDOMONAS AERUGINOSA (COUNTS/100 ML)
PRCP: MILLIMETERS OF PRECIPITATION FOR DAY OF SAMPLING PLUS 2 DAYS PREVIOUS - AVERAGE OF OLD WESTON RD. AND KEELE-FINCH STNS.
*: APPROXIMATE VALUE

TABLE C1 (CONTD.)

BLACK CREEK AT SCARLETT RD. STN. -1977

DAY	MONTH	FC	FS	PRCP	FC/FS
17	5	400.00	60.00	3.05	6.67
15	6	3000.00	-77.00	0.00	-77.00
14	7	1100.00	220.00	0.00	5.00
16	8	3000.00	600.00	5.70	5.00
15	9	1100.00	330.00	14.90	3.33
17	10	1400.00	920.00	6.45	1.52
GEOMEAN:		1351.66	299.37		
NDT:		6	5		
DRY GEOMEAN:		1816.58	220.00		8.26
NDT:		2	1		
WET GEOMEAN:		1165.93	323.33		
NDT:		4	4		

BLACK CREEK AT SCARLETT RD. STN. -1978

DAY	MONTH	FC	FS	PRCP	FC/FS
17	5	2200.00	780.00	3.50	2.82
15	6	40.00	190.00	0.00	0.21
17	7	1100.00	600.00	0.00	1.83
23	8	1030.00	160.00	15.10	6.44
18	9	9000.00	2300.00	44.00	3.91
GEOMEAN:		978.56	504.62		
NDT:		5	5		
DRY GEOMEAN:		209.76	337.64		0.62
NDT:		2	2		
WET GEOMEAN:		2732.11	659.65		
NDT:		3	3		

BLACK CREEK AT SCARLETT RD. STN. -1979

DAY	MONTH	FC	FS	PRCP	FC/FS
25	6	11000.00	1100.00	0.00	10.00
1	8	10000.00	1400.00	31.60	7.14
27	8	-77.00	2200.00	6.50	-77.00
10	10	330.00	1200.00	21.00	0.27
GEOMEAN:		3311.05	1419.97		
NDT:		3	4		
DRY GEOMEAN:		10999.93	1099.99		10.00
NDT:		1	1		
WET GEOMEAN:		1816.58	1546.11		
NDT:		2	3		

BLACK CREEK AT SCARLETT RD. STN. -1980

DAY	MONTH	FC	FS	PRCP	FC/FS
7	5	1500.00	1400.00	3.70	1.07
17	6	8000.00	1800.00	0.00	4.44
GEOMEAN:		3464.08	1587.44		
NDT:		2	2		
DRY GEOMEAN:		7999.95	1799.99		4.44
NDT:		1	1		
WET GEOMEAN:		1499.99	1399.99		
NDT:		1	1		

BLACK CREEK AT SCARLETT RD. STN. -1981

DAY	MONTH	FC	FS	PRCP	FC/FS
12	5	5100.00	1000.00	24.05	5.10
30	6	5000.00	1600.00	2.80	3.13
26	8	9500.00	310.00	0.00	30.65
28	9	* 600.00	200.00	2.75	3.00
GEOMEAN:		3472.17	561.21		
NDT:		4	4		
DRY GEOMEAN:		3054.53	462.92		6.60
NDT:		3	3		
WET GEOMEAN:		5099.97	1000.00		
NDT:		1	1		

-77. : DATA REPORTED AS LESS THAN OR GREATER THAN AND NOT USED
-99. : DATA NOT AVAILABLE
FC: FECAL COLIFORMS (COUNTS/100 ML)
FS: FECAL STREPTOCOCCI (COUNTS/100 ML)
PA: PSUEDOMONAS AERUGINOSA (COUNTS/100 ML)
PRCP: MILLIMETERS OF PRECIPITATION FOR DAY OF SAMPLING PLUS 2 DAYS PREVIOUS - AVERAGE OF OLD WESTON RD. AND KEELE-FINCH STNS.
* : APPROXIMATE VALUE

TABLE C2

TAWMS FALL 1982 AND JULY 1983 DATA

(a) FALL 1982 SURVEYS

HUMBER RIVER AT STEELES AVE. STN.-1982

DAY	MONTH	FC	FS	PRCP	FC/FS
5	10	* 60.00	* 40.00	0.00	1.50
20	10	148.00	275.00	6.80	0.54
26	10	* 50.00	* 30.00	0.00	1.67
3	11	400.00	1909.00	48.80	0.21
22	11	729.00	1372.00	13.70	0.53
GEOMEAN:		166.99	243.97		
NDT:		5	5		
DRY GEOMEAN:		54.77	34.64		1.58
NDT:		2	2		
WET GEOMEAN:		350.76	896.39		
NDT:		3	3		

HUMBER RIVER AT BLOOR ST. STN.-1982

DAY	MONTH	FC	FS	PRCP	FC/FS
5	10	520.00	100.00	0.00	5.20
20	10	905.00	538.00	6.80	1.68
26	10	140.00	80.00	0.00	1.75
3	11	1299.00	3072.00	43.80	0.42
22	11	1157.00	1272.00	13.70	0.91
GEOMEAN:		629.71	441.73		
NDT:		5	5		
DRY GEOMEAN:		269.81	89.44		3.02
NDT:		2	2		
WET GEOMEAN:		1107.97	1281.04		
NDT:		3	3		

HUMBER RIVER AT WEST HUMBER STN.-1982

DAY	MONTH	FC	FS	PRCP	FC/FS
5	10	120.00	100.00	0.00	1.20
20	10	1380.00	3101.00	6.80	0.45
26	10	-99.00	40.00	0.00	-99.00
3	11	214.00	1078.00	48.80	0.20
22	11	712.00	1483.00	13.70	0.48
GEOMEAN:		398.55	456.52		
NDT:		4	5		
DRY GEOMEAN:		120.00	63.25		1.90
NDT:		1	2		
WET GEOMEAN:		594.64	1705.11		
NDT:		3	3		

BLACK CREEK AT LAWRENCE AVE. STN.-1982

DAY	MONTH	FC	FS	PRCP	FC/FS
5	10	1460.00	*180.00	0.00	8.11
20	10	2685.00	7324.00	6.15	0.37
26	10	420.00	340.00	0.00	1.24
3	11	459.00	1347.00	48.80	0.34
21	11	4562.00	6259.00	13.70	0.73
GEOMEAN:		1280.86	1304.58		
NDT:		5	5		
DRY GEOMEAN:		783.07	247.39		3.17
NDT:		2	2		
WET GEOMEAN:		1778.15	3952.48		
NDT:		3	3		

HUMBER RIVER AT LAWRENCE AVE. STN.-1982

DAY	MONTH	FC	FS	PRCP	FC/FS
5	10	* 120.00	* 100.00	0.00	1.20
20	10	1156.00	1360.00	6.15	0.85
26	10	* 20.00	* 30.00	0.00	0.67
3	11	456.00	1959.00	48.80	0.23
22	11	838.00	1236.00	13.70	0.68
GEOMEAN:		254.14	397.07		
NDT:		5	5		
DRY GEOMEAN:		48.99	54.77		0.89
NDT:		2	2		
WET GEOMEAN:		761.59	1487.34		
NDT:		3	3		

BLACK CREEK AT SCARLETT RD. STN.-1982

DAY	MONTH	FC	FS	PRCP	FC/FS
5	10	1360.00	220.00	0.00	6.18
20	10	40114.00	25135.00	6.15	1.60
26	10	4300.00	240.00	0.00	17.92
3	11	1421.00	2360.00	48.80	0.60
21	11	15336.00	13105.00	13.70	1.17
GEOMEAN:		5517.20	2102.08		
NDT:		5	5		
DRY GEOMEAN:		2418.25	229.78		10.52
NDT:		2	2		
WET GEOMEAN:		9561.60	9194.74		
NDT:		3	3		

HUMBER RIVER AT SCARLETT RD. STN.-1982

DAY	MONTH	FC	FS	PRCP	FC/FS
5	10	300.00	340.00	0.00	0.88
20	10	1576.00	1331.00	6.15	1.18
26	10	*30.00	*30.00	0.00	1.00
3	11	400.00	1909.00	48.80	0.21
22	11	807.00	1102.00	13.70	0.73
GEOMEAN:		340.52	491.08		
NDT:		5	5		
DRY GEOMEAN:		94.87	100.99		0.94
NDT:		2	2		
WET GEOMEAN:		798.29	1409.46		
NDT:		3	3		

-99.: DATA NOT AVAILABLE
FC: FECAL COLIFORMS (COUNTS/100 ML)
FS: FECAL STREPTOCOCCI (COUNTS/100 ML)
PA: PSUEDOMONAS AERUGINOSA (COUNTS/100 ML)
PRCP: MILLIMETERS OF PRECIPITATION FOR DAY OF SAMPLING PLUS 2 DAYS PREVIOUS - AVERAGE OF : D WESTON RD. AND KEELE-FINCH STNS.
* : APPROXIMATE VALUE

TABLE C2 (CONTD.)

(B) JULY 1983 SURVEY

STATION	FC	PA
HUMBER RIVER @ STEELES	180	4
HUMBER RIVER @ WEST HUMBER	3000	132
HUMBER RIVER @ LAWRENCE	3700	160
HUMBER RIVER @ SCARLETT	4700	70 B
HUMBER RIVER @ BLOOR	19000	290
BLACK CREEK @ LAWRENCE	40000	890
BLACK CREEK @ SCARLETT	6300	390

B: APPROXIMATE VALUE
FC: FECAL COLIFORMS (COUNTS/100 mL)
PA: P. AERUGINOSA (COUNTS/100 mL)

TABLE C3
DRY WEATHER OUTFALL QUALITY DATA SUMMARY

(A) HUMBER RIVER - STEELES AVE. TO LAKESHORE BLVD.

REACH	NODE	SEWER	DISCHARGE (M^3/S)	FC (COUNTS/ 100ML)	FS (COUNTS/ 100ML)	REMARKS
H	1		3.43000	127.0	88.0	BACKGROUND INPUTS
	2	469	0.00025	20.0	20.0	
		471	0.00600	655.0	300.0	
		473	0.00025	40.0	182.0	
		475	0.00010	340.0	160.0	
		477	0.01000	20.0	40.0	
		479	0.00010	20.0	380.0	
	3	445	0.00100	20.0	590.0	
		449	0.00050	40.0	180.0	
		451	0.00063	1482.0	693.0	
		455	0.00150	4695.0	329.0	
		459	0.00050	40.0	530.0	
		463	0.00054	100.0	40.0	
		465	0.00150	2683.0	107.0	
	4	441	0.00250	10.0	160.0	
		443	0.00050	10.0	844.0	
		483	0.00100	10.0	10.0	
		677	0.00100	50.0	2200.0	
		679	0.00100	330.0	230.0	
G	5					
	6	254	0.00075	67.8	259.2	
		256	0.00010	510.0	10.0	
		376	0.00010	5500.0	2900.0	
		382	0.00010	2300.0	3100.0	
		384	0.00025	1500.0	290.0	
	7	250	0.00100	5900.0	1500.0	
		252	0.00022	11334.5	4298.4	
		264	0.00081	1648.4	1461.2	
		266	0.00100	260.0	60.0	
		270	0.00980	768.1	2511.6	
		378	0.00010	25210.1	16505.6	
F	8	998	0.40000	106.0	45.0	WEST HUMBER R.
	9	170	0.00200	80.0	330.0	
	10	184	0.00050	600.0	30.0	
		198	0.00001	270.0	150.0	
		204	0.00150	10.0	10.0	
		318	0.00010	100.0	120.0	
		320	0.00300	90.0	80.0	

TABLE C3 (CONTD.)

E	11	162	0.00010	151.7	1570.0	
		164	0.00073	148.0	1419.0	
		180	0.00052	2000.7	4467.6	
	12	118	0.00123	316.1	79.4	
		120	0.00080	282.0	2261.3	
		122	0.00043	938.1	998.0	
		160	0.00026	31.6	1336.0	
		466	0.00200	160.0	600.0	
	13	114	0.00040	1255.0	2934.3	
		116	0.00040	260.0	190.0	
		132	0.00138	603.3	275.7	
		152	0.00100	631.6	684.1	
D	14	106	0.00051	52571.0	1581.5	
	15	36	0.00044	1010.0	1267.0	
		37	0.00017	89365.0	7338.0	
		38	0.00010	20.0	10.0	
		39	0.00150	664.0	134.0	
		40	0.00001	40.0	70.0	
		47	0.00100	50.0	380.0	
		53	0.00010	170.0	290.0	
	16	29	0.00088	77.0	115.0	
		31	0.00013	30.0	240.0	
		33	0.00025	10.0	70.0	
		50	0.00150	120.0	680.0	
		60	0.00030	384.0	240.0	
		70	0.00025	10.0	530.0	
		72	0.00010	30.0	310.0	
		80	0.00025	10.0	10.0	
		82	0.00025	10.0	10.0	
		326	0.00155	57.0	335.0	
		336	0.00025	50.0	30.0	
		354	0.01500	1338.0	2981.0	
		448	0.00025	10.0	10.0	
C	17	25	0.00010	4.0	4.0	
		27	0.00027	16.0	410.0	
		34	0.00100	10.0	10.0	
	18	21	0.00110	88.0	1500.0	
		23	0.00075	124.0	4.0	
		30	0.00200	80.0	140.0	
		32	0.00150	42506.0	500.0	
		535	0.00005	1600.0	7900.0	
		537	0.01000	620.0	420.0	
	19	17	0.00738	81.0	72.0	
		55	0.00018	102.0	58.0	
		63	0.00037	20.0	50.0	
		435	0.00200	670.0	770.0	
		531	0.00500	30.0	110.0	
	20	28	0.00001	37000.0	2600.0	
		525	0.00250	20.0	210.0	
		999	0.19540	4548.0	538.0	BLACK CREEK

TABLE C3 (CONTD.)

B	21	2	0.01500	1500.0	793.0
		22	0.00020	40.0	70.0
		523	0.00250	30.0	110.0
	22	7	0.00025	2300.0	7500.0
		10	0.00050	8385.0	1549.0
		11	0.00007	234.0	569.0
		12	0.00400	2291.0	569.0
		14	0.00018	39.0	69.0
		18	0.00175	38391.0	14625.0
		20	0.00009	2940.0	2077.0
		519	0.00001	170.0	150.0
	23	1	0.00015	2140.0	3558.0
		3	0.00500	190.0	250.0
		4	0.00055	27111.0	10173.0
		6	0.00100	8916.0	73.0
		434	0.00010	190.0	10.0
		509	0.00625	2468.0	2049.0
A	24	296	0.00056	1494.0	511.0
		298	0.00094	162.0	328.0
		300	0.00010	15649.0	7304.0
	25	284	0.00023	315.0	329.0
		286	0.00006	3478.0	7999.0
		288	0.00063	545.0	55.0
		290	0.00200	10.0	20.0
		292	0.00018	10.0	10.0
		294	0.00050	1185.0	346.0
		503	0.00050	1099.0	872.0
		507	0.01000	610.0	750.0
	26	272	0.00010	80.0	40.0
		280	0.00050	10.0	140.0
		489	0.00010	80.0	90.0
		493	0.00120	266.0	262.0
		497	0.00200	338.0	1871.0
		499	0.00500	473.0	455.0

TABLE C3 (CONTD.)

(B) BLACK CREEK - LAWRENCE AVENUE TO HUMBER RIVER CONFLUENCE

REACH	NODE	SEWER	DISCHARGE (M^3/S)	FC (COUNTS/ 100ML)	FS (COUNTS/ 100ML)	REMARKS
M	1		0.09000	1296.0	530.0	BACKGROUND INPUTS
	1	213	0.00021	17.0	100.0	
		215	0.00050	10.0	20.0	
		217	0.00325	219.0	684.0	
		219	0.00036	260.0	479.0	
	2	195	0.00100	10.0	80.0	
		197	0.00100	20.0	60.0	
		207	0.00200	100.0	470.0	
		209	0.00250	1500.0	1700.0	
		597	0.00050	1900.0	930.0	
	3	177	0.00050	114.0	109.0	
		185	0.00037	1117.0	4947.0	
		191	0.00131	48.0	181.0	
		193	0.01000	7304.0	3078.0	
		589	0.00250	750.0	750.0	
	4	171	0.00050	4000.0	200.0	
		173	0.00050	30.0	90.0	
		175	0.00600	1700.0	680.0	
		179	0.00038	13927.0	2385.0	
		181	0.00025	124237.0	20777.0	
L	5					
	6	135	0.00300	14747.0	1576.0	
		139	0.00350	231.0	22.0	
		145	0.00005	10.0	10.0	
		147	0.00075	190.0	30.0	
		151	0.00010	530.0	280.0	
		165	0.00246	4479.0	2451.0	
		607	0.00050	40.0	30.0	
	7	87	0.00008	74631.0	507.0	
		89	0.00025	10.0	10.0	
		93	0.00200	220.0	50.0	
		97	0.00500	1554.0	165.0	
		105	0.00050	580.0	390.0	
		109	0.00500	6082.0	2078.0	
		123	0.00006	500219.0	810375.0	
		125	0.00018	779618.0	465390.0	
		127	0.01000	758.0	1189.0	
		129	0.00500	2956.0	2794.0	
	8	67	0.00005	120.0	10.0	
		69	0.00050	516768.0	21703.0	
		71	0.00024	25943.0	664.0	
		75	0.00010	626039.0	7270.0	
		83	0.00025	169.0	91.0	
		85	0.00015	136302.0	2325.0	
		557	0.00150	20.0	20.0	

APPENDIX D

MEDIA FOR ENTEROCOCCI AND *E. COLI*

Enterococci

Modified mE Agar

Ingredients	Grams/litre
Peptone	10.0
Yeast Extract	30.0
NaCl	15.0
Sodium Azide	0.15
Actidione (Cycloheximide)	0.05
Agar	15.0

The above ingredients are mixed into one litre distilled water, heated to 90°C to dissolve the agar, autoclaved for 15 minutes (15 Psi, 121°C) and cooled above base to 55 - 60°C. Then, aseptically, the following are added:

1. Nalidixic Acid
   - 240 mg in 3 mL sterile distilled water plus 0.2 mL ion NaOH
   - Mix and add to base

2. Indoxyl-B-D-Glucoside
   - 750 mg in 5 mL 95% ethanol
   - Mix well then add 5 mL sterile distilled water
   - Mix all above and add to base

3. Triphenyltetrazolium Chloride (T.T.C.)
   - 20 mg
   - Add to base just before pouring

The prepared medium is then dispensed into sterile petri plates (final surface pH:7.1±0.1).

E. coli

mTEC-IG Agar

Ingredients	Grams/litre
Proteose Peptone (Difco 0120-01)	5.0
Yeast Extract (Difco 0127-01)	3.0
Lactose (L-5 75212 Fisher)	10.0
NaCl	7.5
K_2HPO_4 (7092 Mallinckrodt)	3.3
KH_2PO_4 (P382 Fisher)	1.0
Sodium Lauryl Sulfate (2003 Matheson, Coleman & Bell)	0.2
Sodium Desoxycholate (S-285 Fisher)	0.1
Brom Cresol Purple (4223 Nutritional Bio. Co.)	0.08
Brom Phenol Red (NB117 M-C and Bell)	0.08
Agar (Difco)	15
Distilled Water	To one litre

The ingredients are dissolved by stirring, sterilizing by autoclaving at 121°C for 15 minutes. Cool to 45°C and add 5 ml Indoxyl-B-D-glucoside solution (0.25 gm dissolved in 5 ml ethyl alcohol). Pour 4 ml portions into 10 x 47 mm plates. The pH of the medium is 7.3.

APPENDIX E

EXAMPLE OF GEOMETRIC MEAN DENSITY COMPUTATION

EXAMPLE OF GEOMETRIC MEAN DENSITY COMPUTATION

This example shows the procedure utilized to compute the geometric mean bacterial density when the laboratory result is less than some value (X_r). A brief description of the procedure has been given in Section 3.1 (see Chapter III).

Enterococci density data, given in Table A1 (Appendix A) are utilized in this example. The density for one of the dry weather surveys (Event 9) is <2 counts/100 mL. Therefore, $X_r = 2.0$. The values (X) reported by the laboratory and the values $(X + X_r)$ are given below.

Lab Value (X)	8	28	10	16	26	22	16	16	<2	10
$(X + X_r)$	10	30	12	18	28	24	18	18	2	12

The apparent geometric mean (X'_g) of the $(X + X_r)$ values is:

$$X'_g = 14.2 \text{ counts/100 mL.}$$

Thus, the geometric mean value (X_g) is $(14.2 - 2.0) = 12.2$ counts/100 mL.